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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

MAR 25 1994

94-LWB-020

Mr. Robert Kayser
Office of Solid Waste
U.S. Environmental Protection Agency
401 M Street SW, Mail Stop OF-343
Washington D.C. 20460

9413275.1703

Dear Sir:

GROUNDWATER STUDY AND SUMMARY OF GROUNDWATER INVESTIGATIONS RELATED TO THE 200 AREA EFFLUENT TREATMENT FACILITY AND THE STATE-APPROVED LAND DISPOSAL SITE

On July 30, 1993, a meeting was held between the U.S. Environmental Protection Agency (EPA) Headquarters, U.S. Department of Energy, Richland Operations Office, (DOE-RL) and Westinghouse Hanford Company (WHC) on the Delisting Petition for the 200 Area Effluent Treatment (ETF) and the State-Approved Land Disposal Site (SALDS). At the meeting, the EPA wanted an additional study focusing on the migration of constituents other than tritium. This study would evaluate the transport of constituents other than tritium using the existing model developed by Golder Associates without the decay rate for tritium.

In a follow-up discussion between the EPA , WHC, and Golder Associates on September 9, 1993 to clarify this request, it was decided that this study would provide a dilution factor or ratio at the Columbia River using existing data without the decay effect to tritium. Enclosure 1, titled, "Migration of Non decaying and Nonretarding Constituents from the State-Approved Land Disposal Site, Hanford Site, Washington" fulfills this request. It should be noted that several conservative assumptions were used in the model that will tend to overestimate the actual concentrations and mass flux values. The assumptions used can be found in Section 5.0, Evaluation of Results.

In subsequent conversations between the EPA and WHC, it was noted that a "road map", or summary and overview of the groundwater investigations performed at the SALDS in support of the ETF would be helpful to the EPA. Enclosure 2 provides a list of the documents that describe the related groundwater investigations and is followed by a brief summary and description of these documents.

Should you have any questions on this, please contact Mr. P. J. Krupin on (509) 372-1112 or Mr. D. C. Bryson on (509) 372-0738.

Sincerely,

Dim R. Clausen for
June M. Hennig, Director
Waste Management Division

WMD:JDB

Enclosure:
1. Groundwater Modeling Study
2. Summary of Groundwater Investigations

cc: N. Chaudhari, EPA HQ, w/encl.
D. Jansen, Ecology
J. J. Luke, WHC
M. Selby, Ecolgy, w/encl.
D. R. Sherwood, EPA Region X, w/encl.
J. E. Thrasher, WHC

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MIGRATION OF NONDECAYING AND NONRETARDING CONSTITUENTS FROM THE STATE-APPROVED LAND DISPOSAL SITE, HANFORD SITE, WASHINGTON

Prepared for

Westinghouse Hanford Company
P.O. Box 1970
Richland, Washington 99352

Prepared by

Golder Associates Inc.
Richland, Washington

WHC Contract No. MLW-SVV-073750
Task Order S-93-26
SAIC Project No. 01-1011-03-4546

January 19, 1994

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1.0 INTRODUCTION

A land disposal site north of the 200-West Area has been selected for disposal of tritium-bearing waste streams on the Hanford Site. The disposal site is called the Hanford State-Approved Land Disposal Site (SALDS). Its selection was based in part, upon the computer simulations of tritium plume migration summarized in the report *Groundwater Mounding and Plume Migration Analyses for Candidate Soil Column Disposal Sites, Hanford Site, Washington* (WHC 1991). That report is also presented as Appendix C of a Westinghouse Hanford Company wastewater engineering alternative report (WHC 1993).

The original siting analysis addressed only tritium migration, and did not consider the migration of other constituents that may be present in the waste. The objective of this study is to develop generic information on the migration of nondecaying, nonretarding chemical constituents that may be present with the tritium in the waste stream. The results are intended to provide, through the use of unit source concentrations, a means of conservatively estimating the concentrations and mass flux of such constituents in the groundwater prior to their release into the Columbia River. This study is considered an extension of the earlier study, and the same model has been used for both.

2.0 HANFORD SITE GROUNDWATER FLOW AND TRANSPORT MODEL

2.1 Model Development

The numerical modeling was performed using two two-dimensional finite element computer codes that are parts of the Golder Groundwater Computer Package (GGWP) (GAI 1993). The steady state groundwater flow field was simulated using the Aquifer Flow in Porous Media (AFPM) code, and the transient solute transport was simulated using the Solute Transport (SOLTR) code. The location of the disposal site within the region simulated by the model is shown in Figure 1. The finite element grid used in the modeling is shown in Figure 2, and is the same as in the previous study.

The model input parameters were unchanged from those used in the aforementioned study, with the following exceptions:

- The radioactive decay term, originally assumed for tritium in the previous model simulations, was set to zero to simulate a nondecaying constituent; and

- The concentration at the plume source in the groundwater, originally assumed for the expected actual tritium concentration, was set to the unit value of 1 mg/L.

Neither this nor the original modeling study considers retardation. The modifications made to the model will allow the migration of a generic, nondecaying and nonretarded chemical constituent to be estimated. The approach is conservative, and will tend to underestimate actual travel times and concentrations because most constituents are retarded by sorption/desorption and other chemical processes, and many will decay over time because of biological or radiological processes.

The approach is considered generic because the concentration of any specific constituent can be readily estimated from the modeling results if the actual source concentration is known. This is because of the linear relationship between the concentration and the other terms in the governing equation, when time-dependent decay is ignored. The concentration of any specific constituent is equal to its concentration at the source multiplied by the model-predicted concentration at any point in the flow field. The mass flux of any specific constituent may also be determined in a similar manner, provided that the volumetric discharge rate of the waste stream is the same as that assumed for the model. The modeling results are valid only for that discharge rate, and different plume characteristics and concentrations would be expected if the discharge rate varied.

2.2 Input Parameters and Assumptions

The development, validation, and application of the groundwater flow and solute transport models are described in detail in the report documenting the previous study (WHC 1991). Two-dimensional modeling cannot address the vertical concentration gradients that will be present within the aquifer. Because of this limitation and the generic nature of this study, average concentrations across the thickness of the aquifer are reported. In nature, however, higher concentrations would be expected in the upper part of the aquifer, and lower concentrations in the lower part. Because all aquifer water is considered to discharge into the Columbia River, the estimated chemical mass flux into the river will be essentially unaffected by ignoring the third dimension.

A continuous waste water discharge rate of 150 gallons per minute (gpm) was assumed in the modeling, and is the same as in the previous study (WHC 1991). As before, the disposal pond was assumed to be rectangular with dimensions of 220 ft by 100 ft. It was then assumed that as the effluent seeps through the unsaturated zone, it spreads with an angle from the vertical of 20°. As explained in the previous report, this value is consistent with data from a tank leak at the Hanford Site reported by Smoot et al. (1989). After migration through the approximately 220-foot thick unsaturated zone at the disposal site, the source area at the water table was assumed to be about 90,000 ft^2. The approach used to determine the size of the source at the water table is shown schematically in Figure 3, and the finite element grid in the immediate vicinity of the source is shown in Figure 4.

The effect of B-Pond was also included in the model to permit evaluation of plume development under current groundwater flow conditions. Inclusion of B-Pond is conservative, because the discharge from the pond increases hydraulic gradients through Gable Mountain Gap, and therefore increases groundwater flow rates toward the river. The assumed flux from B-Pond was 16.5 million gallons per day (mgd). Discharges into B-Pond strongly influence the direction and rate of groundwater movement in the Cold Creek Syncline, and different results would be expected from this modeling effort if discharges to B-Pond were significantly increased or decreased.

The hydrologic and transport properties of the geologic media were estimated from Hanford Site data, and from published data from other sites. Where uncertainties in parameter values were encountered, conservative estimates were made. Although dispersivity values are scale dependent, a constant dispersivity was in the model. To gain modeling accuracy at points of discharge along the Columbia River, the dispersivity used in the model was based on a large scale of interest (approximately 31,000 ft). The parameter values were the same as used in the previous study (WHC 1991), and are explained in detail in the aforementioned report.

Maps showing groundwater equipotentials in the simulated region and in the immediate vicinity of the disposal site are shown in Figures 5 and 6, respectively. A map of the predicted groundwater mound beneath the site under steady-state flow conditions is shown in Figure 7. Each of these figures is essentially the same as the parallel figure from the previous study (WHC 1991), and demonstrates the equivalency of the two studies.

3.0 LIMITATIONS OF THE MODELS

Any modeling effort requires simplification of the physical process being modeled, which introduces limitations into the model results. A detailed discussion of these limitations is presented in the previous report (WHC 1991), and they will only be highlighted here. None of these limitations are expected to change the conclusions regarding the principal objectives of this study.

- Two-dimensional modeling of a three-dimensional system cannot address effects resulting from vertical variations in conditions or processes. However, the results obtained from two-dimensional models are considered to be entirely adequate for the purposes of this study.

- Parameter values must be estimated if they are not available from site-specific measurements. Conservative estimates were used for this modeling such that constituent concentrations at the Columbia River would tend to be overestimated.

- If dispersivities representative of large scale distances are used, errors in plume shape are introduced near the source. Dispersivities used in this modeling are considered to be appropriate for studying constituent concentrations at the Columbia River; predicted plume geometries near the source are expected to be less accurate, but this will not affect the primary objectives of the study.

- The source term concentration and geometry is uncertain because of migration through the thick unsaturated zone. As a result, predicted plume geometries are expected to be less accurate near the source, but this will not affect the primary objectives of the study.

4.0 MODEL RESULTS

Model predictions of the progressive development of the plume beneath the disposal site are shown in Figures 8 through 13. These plumes depict the migration of a nondecaying, nonretarded chemical constituent released to the groundwater beneath the disposal site in a 150 gpm effluent stream at a concentration of 1 mg/L. The concentration values represent the average constituent concentration across the thickness of the aquifer. Only the northern part of the simulated region is shown. The irregularly shaped areas within the model domain represent subcrops of low permeability basalt bedrock that rise above the water table.

Figure 8 shows the predicted plume geometry 25 years after startup of effluent discharge. The plume has a regular, somewhat elliptical shape reflective of the fairly uniform groundwater flow field and transmissivity in this area. Figure 9 shows the plume geometry after 50 years. Here the movement toward Gable Mountain Gap is clearly evident. After 75 years, as shown in Figure 10, the plume is nearly to the gap and is just about to enter a higher transmissivity zone that passes through the gap. After 100 years, as shown in Figure 11, the leading edge of the plume has passed quickly through the gap and is curling around the north side of Gable Butte. This movement reflects the influence of B-Pond, which causes a significant groundwater flow through the gap that limits groundwater from the west side of the Site to the west side of the gap.

Figure 12 shows the predicted shape of the plume after 200 years. At this time the leading edge of the plume has reached the river. Additional modeling was conducted at 100-year intervals to 700 years. No significant changes were observed past 300 years, indicating that the plume had essentially reached steady state. Predicted groundwater concentration 300 years after disposal facility startup are shown in Figure 13.

Figure 14 is a plot of generic constituent concentrations in the groundwater at the river. Again, these are average concentrations across the thickness of the aquifer, based upon a unit source concentration, and are therefore normalized average concentrations for the groundwater discharging into the river. Actual concentrations may be higher in seeps along the river shore and lower in groundwater discharging into the river bottom sediments. The plot is drawn from the perspective of looking toward the river, thus the zero distance is on the upstream end of the profile. It should be noted that the graphical convention used to locate the zero point is different than in the corresponding figures of the earlier study (WHC 1991).

The groundwater concentrations are plotted in Figure 14 against model boundary distances for time periods of 100, 200, and 300 years. The curves shown in the figure represent the best fit fifth-order polynomial regression to the raw model output data. A regression curve was used to smooth the high frequency variations in the model output resulting from boundary effects, and thereby facilitate interpretation of the results. At 100 years, the model predicts concentrations that are near zero, and are too low to show up on the plume map in Figure 11. At 200 years, the concentrations have increased substantially, and the downriver elongation of the plume is evident. As the plume approaches steady state, the primary change is in the peak concentration and little additional plume spreading is observed. After 300 years, the plume is essentially at steady state and further increases in peak concentrations were not observed in the modeling.

The generic mass flux discharge of the constituent is plotted in Figure 15 against model boundary distances for the same time periods as in the previous figures. Again, the plotted curves represent the best fit fifth-order polynomial regression to the raw model output data. After 100 years, the mass flux discharge into the river is estimated to be very low. After 200 years, the mass flux has increased significantly and is close to steady state. After 300 years, the plume is essentially at steady state and further significant increases in mass flux were not predicted.

5.0 EVALUATION OF RESULTS

Because a unit source concentration of 1 mg/L was used in the model, the concentration of any specific chemical constituent in the groundwater along the river can be estimated by multiplying the normalized concentration shown in Figure 14 by the actual concentration in milligrams per liter of that constituent in the waste effluent. In interpreting the figure, the results shown are not intended to present a high resolution prediction of groundwater concentrations along the river, but instead have been generalized to identify trends. The distances shown in Figure 14 are model boundary distances. Because of the right angle steps in the model boundary, the cumulative distance along which discharges to the river are predicted is longer than the actual river length in this area. It may be concluded from Figure 14 that the peak constituent concentration along a 2-mile stretch of river is predicted to be close to zero after 100 years, about 7% to 8% of the source concentration after 200 years, and reach steady state at about 11% of the source concentration after 300 years. In reality, the disposal facility and its source processes may not operate for even 100 years, in which case the average concentration at the river would peak at less than the steady state value, and then decline over time to zero.

The mass flux is equal to the concentrations in Figure 14 multiplied by the volumetric groundwater flow rates entering the Columbia River from the associated boundary elements in the model. The mass flux of any specific chemical may therefore be estimated by multiplying the normalized mass flux shown in Figure 15 by the actual concentration in milligrams per liter of that constituent in the waste effluent. This relationship will be valid so long as the effluent discharge rate at the source remains approximately 150 gpm. Again, the results should be considered generally indicative of the type of mass flux distribution that should be expected, but not of the localized effects of specific higher or lower transmissivity zones that may be present.

The areas under the curves in Figure 15 may be used to provide an estimate of the total mass flux entering the river from the disposal site. Figure 16 shows a plot of these values, normalized by dividing by the constant mass flux being discharged at the disposal site. At time periods of less than 100 years, this ratio is near zero, indicating essentially no discharge into the river. After 100 years, this ratio is perceptibly greater than zero, but is still small. After 200 years the ratio is approximately 75%, indicating that the rate of discharge into the river is about 75% of the constant mass flux being discharged at the disposal site. After 300 years this ratio is about 98%, and after 400 years it is essentially 100% and is clearly at steady state. Thus after 400 years, the rate of chemical discharge into the river is equal to the rate of discharge at the disposal site. Again, these relations are valid only for a 150 gpm effluent discharge rate at the source.

The results of this study can be used to conservatively estimate the concentrations and mass flux of nondecaying, nonretarding chemical constituents entering the Columbia River from a 150 gpm waste stream discharged at the SALDS facility. It is important to recognize that a number of conservative and simplifying assumptions have been used in this study that will tend to overestimate the actual concentration and mass flux values that would occur. The more important of these assumptions are as follows:

- an infinite facility lifetime,
- no saturated zone retardation,
- an infinite B-Pond lifetime,
- no unsaturated zone retardation,
- no biological decay of organics, and
- lower transverse and higher longitudinal dispersivity values.

If estimates based on this study are found to be unacceptably high, a more refined analysis may be appropriate to determine if the higher concentrations and fluxes are simply artifacts of the analytical approach, and would not actually be expected to occur. In performing a refined analysis, the following modifications could be considered and would be expected to have a significant effect on the results obtained.

- Remove B-Pond discharges from the model. It is understood that use of B-Pond is planned to be discontinued within the next ten years. This would be expected to reduce the groundwater flow velocity toward the river and permit a wider dispersion of the plume in the area north of Gable Mountain Gap.

- Incorporate the expected SALDS facility lifetime into the model. This would limit the lifetime of the plume and provide a better estimate of the maximum concentrations and fluxes to be expected at the river.

- Incorporate a conservative retardation factor into the model. This would better reflect the migration rates of actual chemicals, and would increase the travel time to the river.

6.0 REFERENCES

GAI, 1993, *Golder Groundwater Package, User and Theory Manuals,* Golder Associates Inc., Redmond, Washington.

Smoot, J.L., J.E. Szecsody, B. Sagar, G.W. Gee, and C.T. Kincaid (1989), *Simulations of Infiltration of Meteoric Water and Contaminant Plume Movement in the Vadose Zone at Single-Shell Tank 241-T-106 at the Hanford Site,* WHC-EP-0332, Westinghouse Hanford Company, Richland, Washington.

WHC, 1991, *Groundwater Mounding and Plume Migration Analyses for Candidate Soil Column Disposal Sites, Hanford Site, Washington,* WHC-MR-0276, Westinghouse Hanford Company, Richland, Washington.

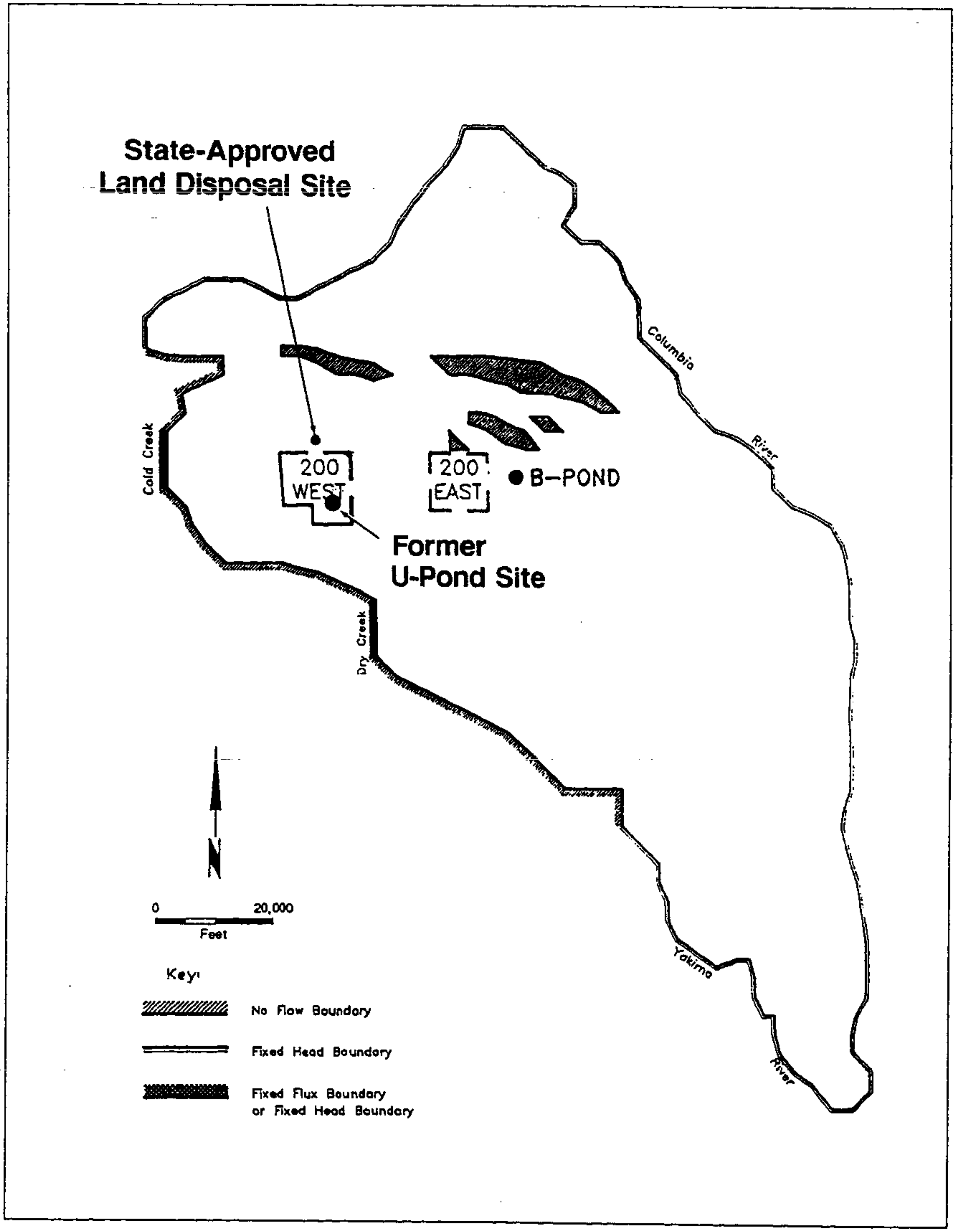

Figure 1. Simulated Region.

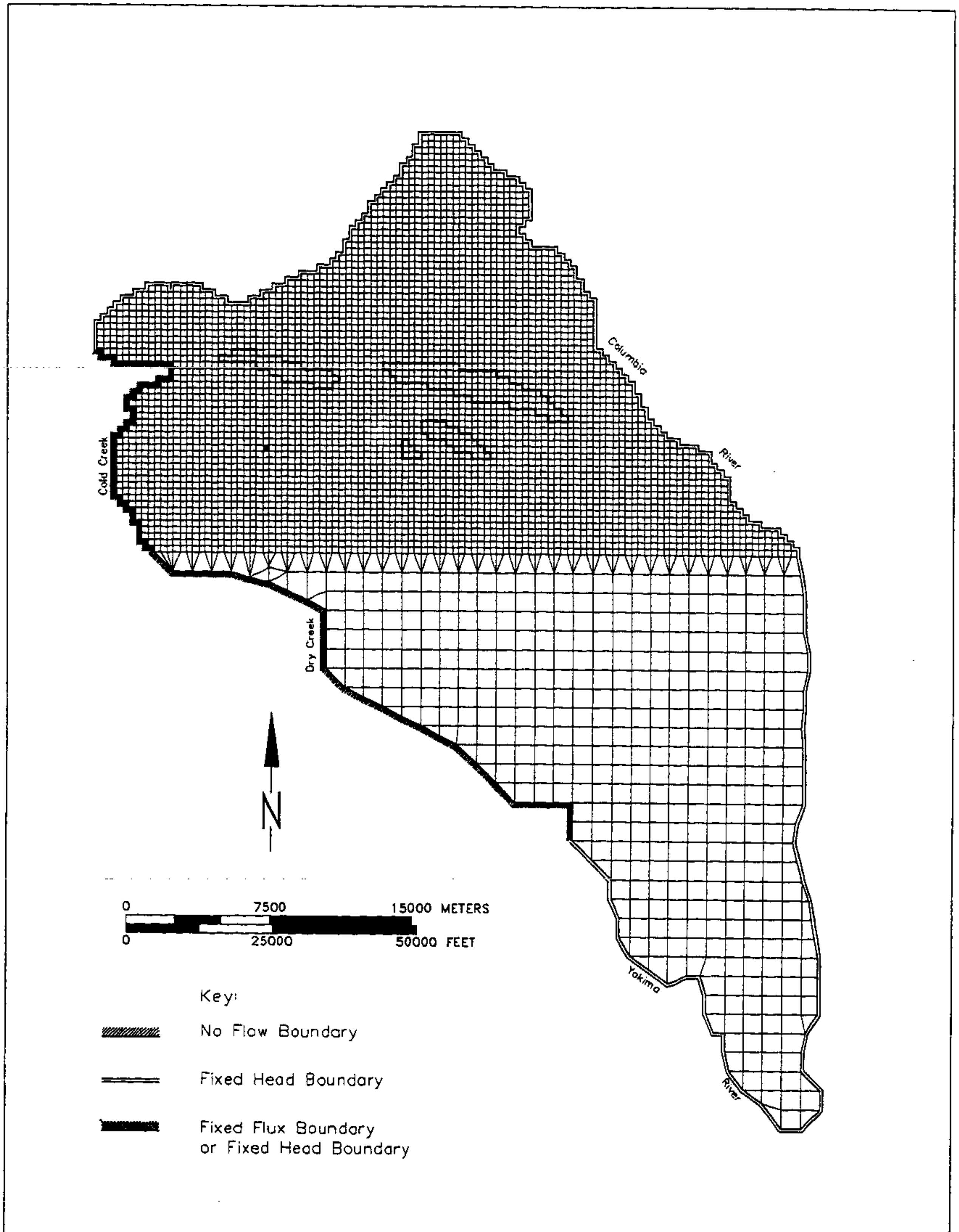

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Figure 2. Finite Element Grid.

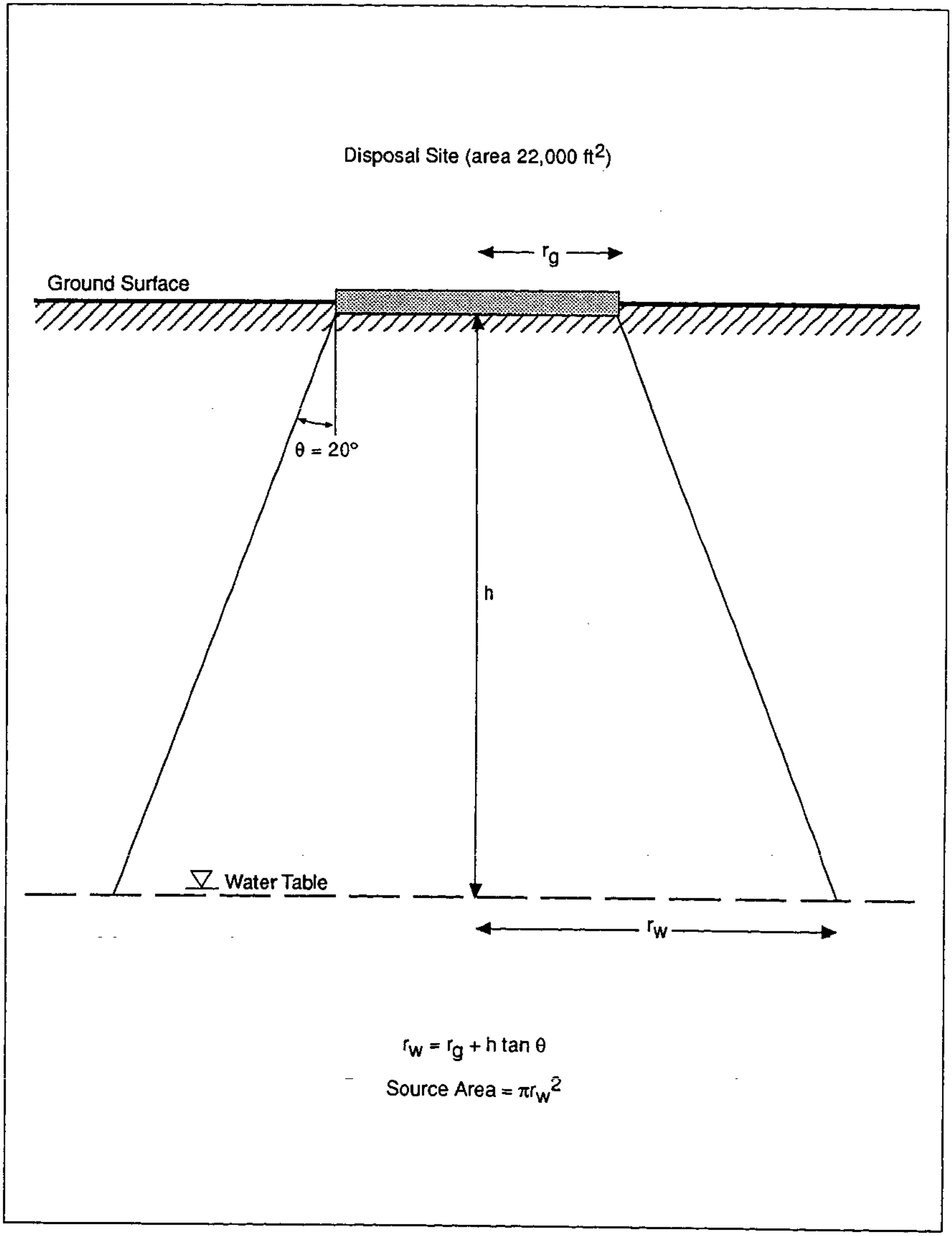

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Figure 3. Source Representation.

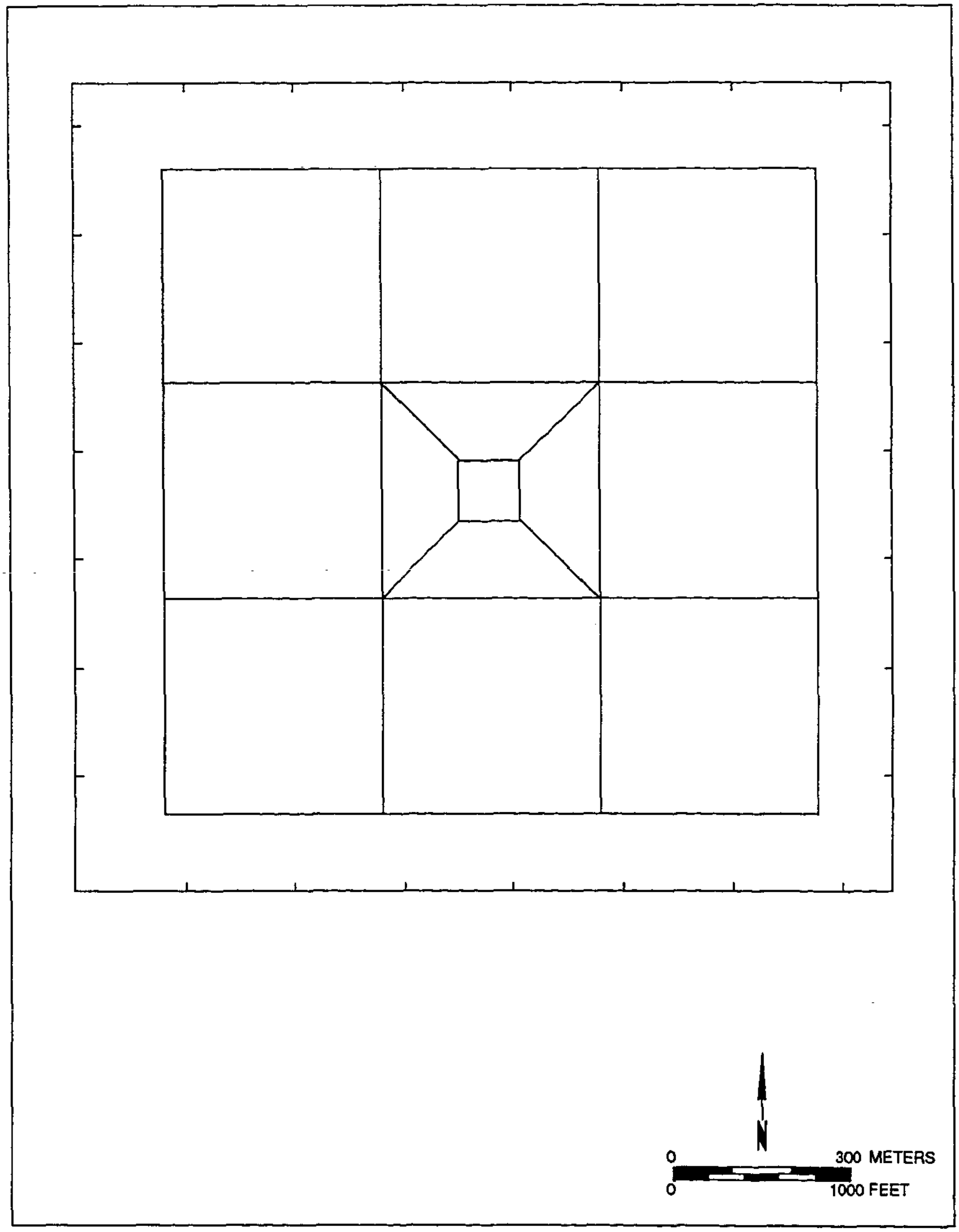

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Figure 4. SALDS Discretization.

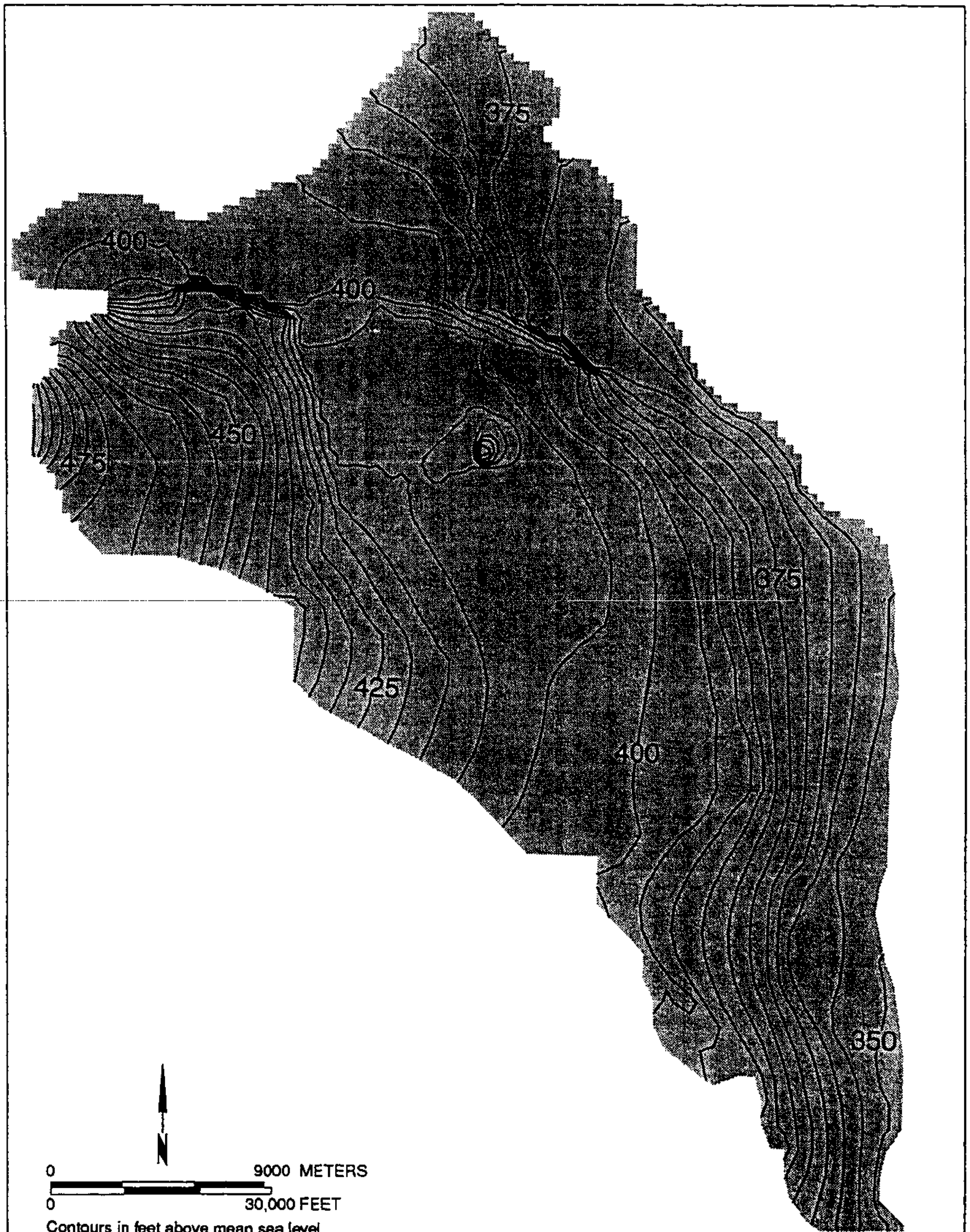

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Figure 5. Equipotentials with Disposal at SALDS.

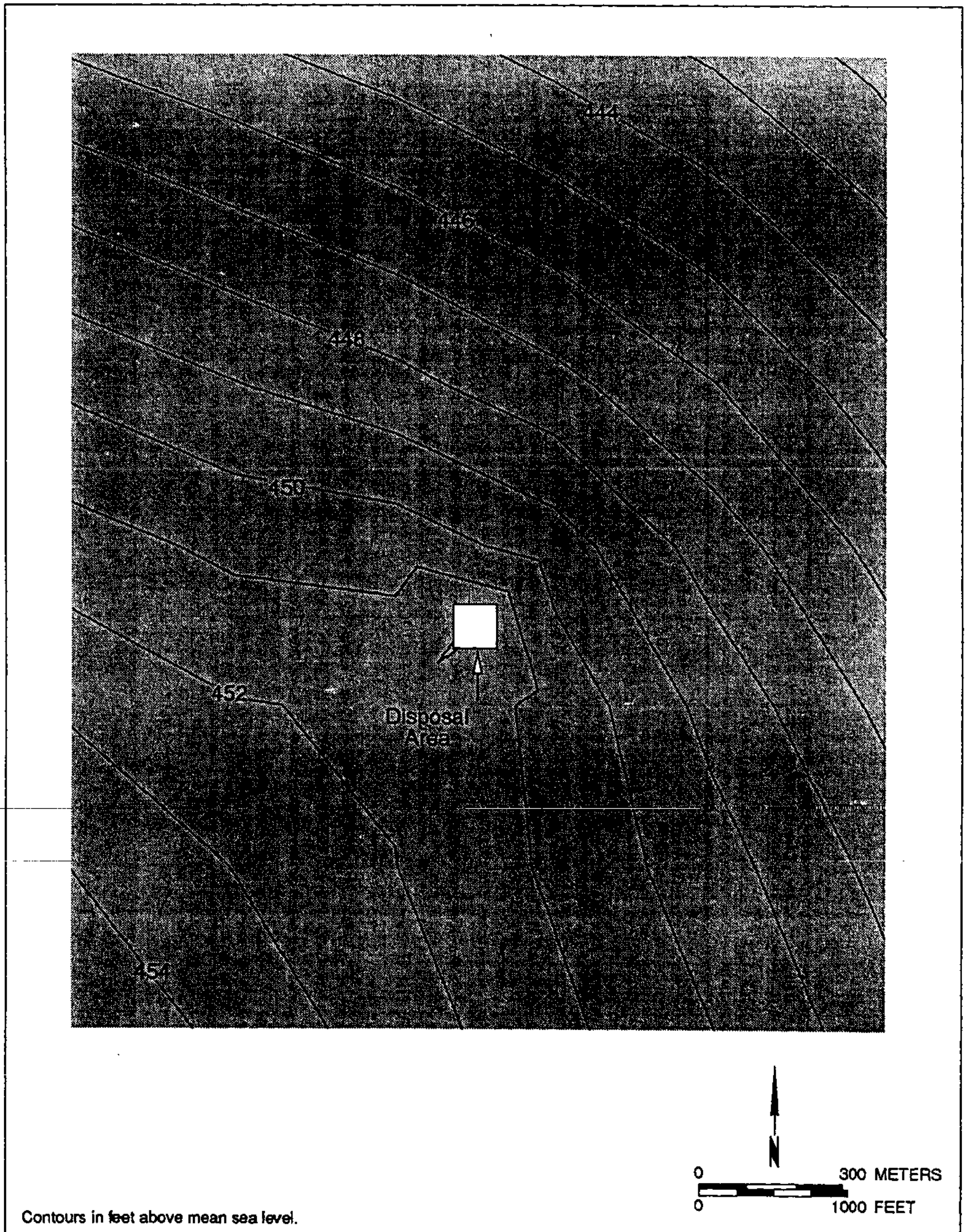

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Figure 6. Equipotentials Near SALDS.

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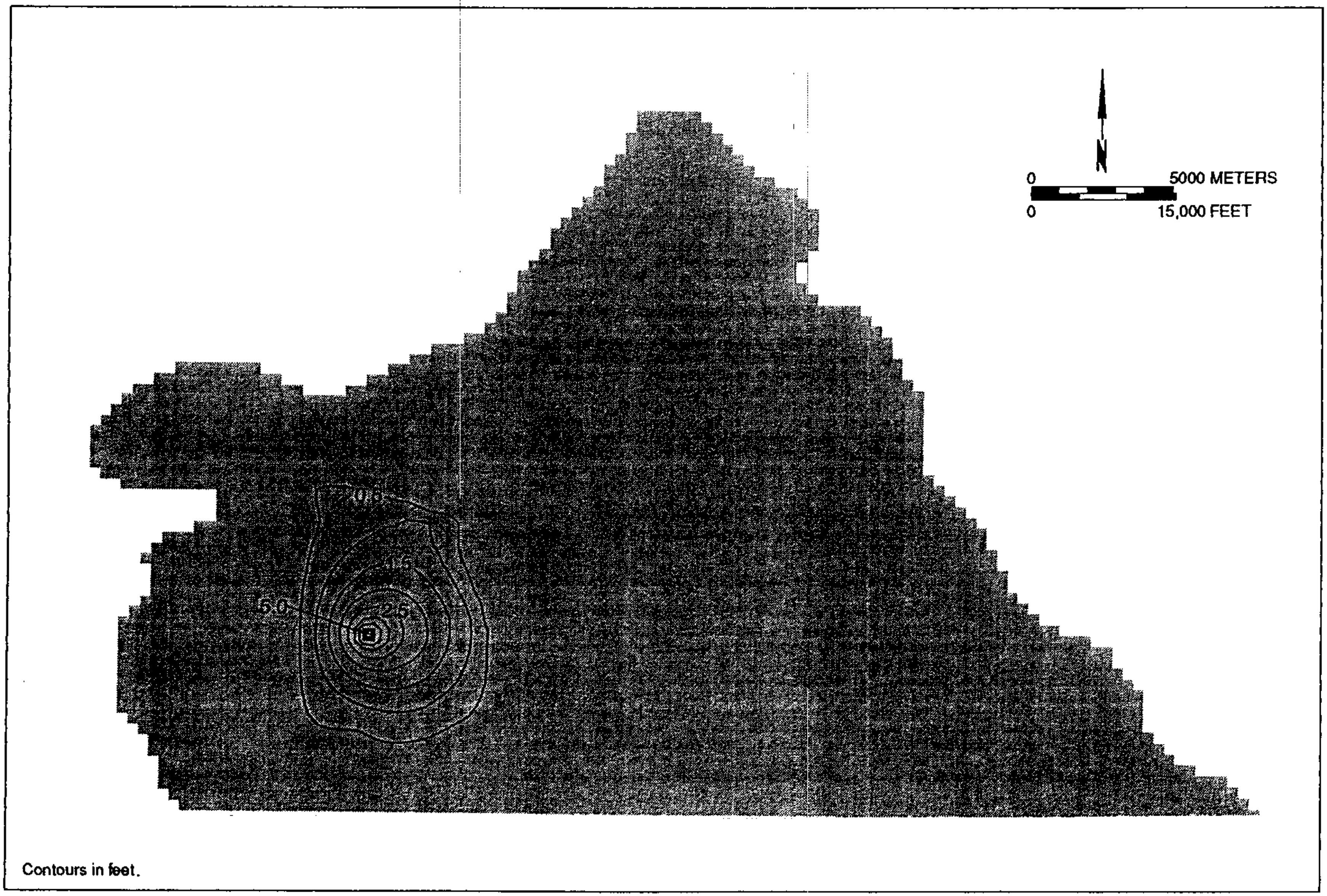

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Figure 7. Mound Formed Around SALDS.

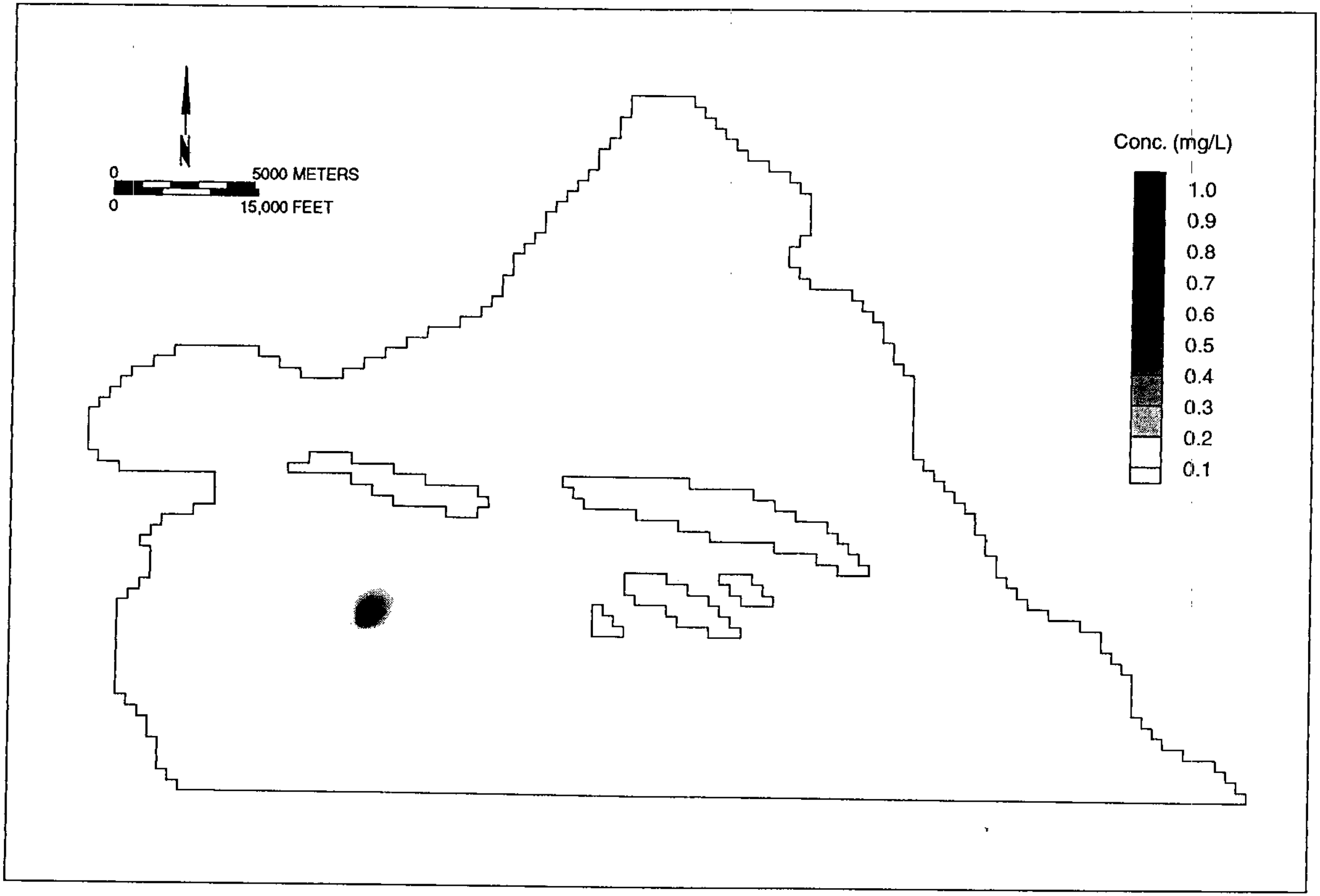

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Figure 8. Concentration Contours After 25 Years.

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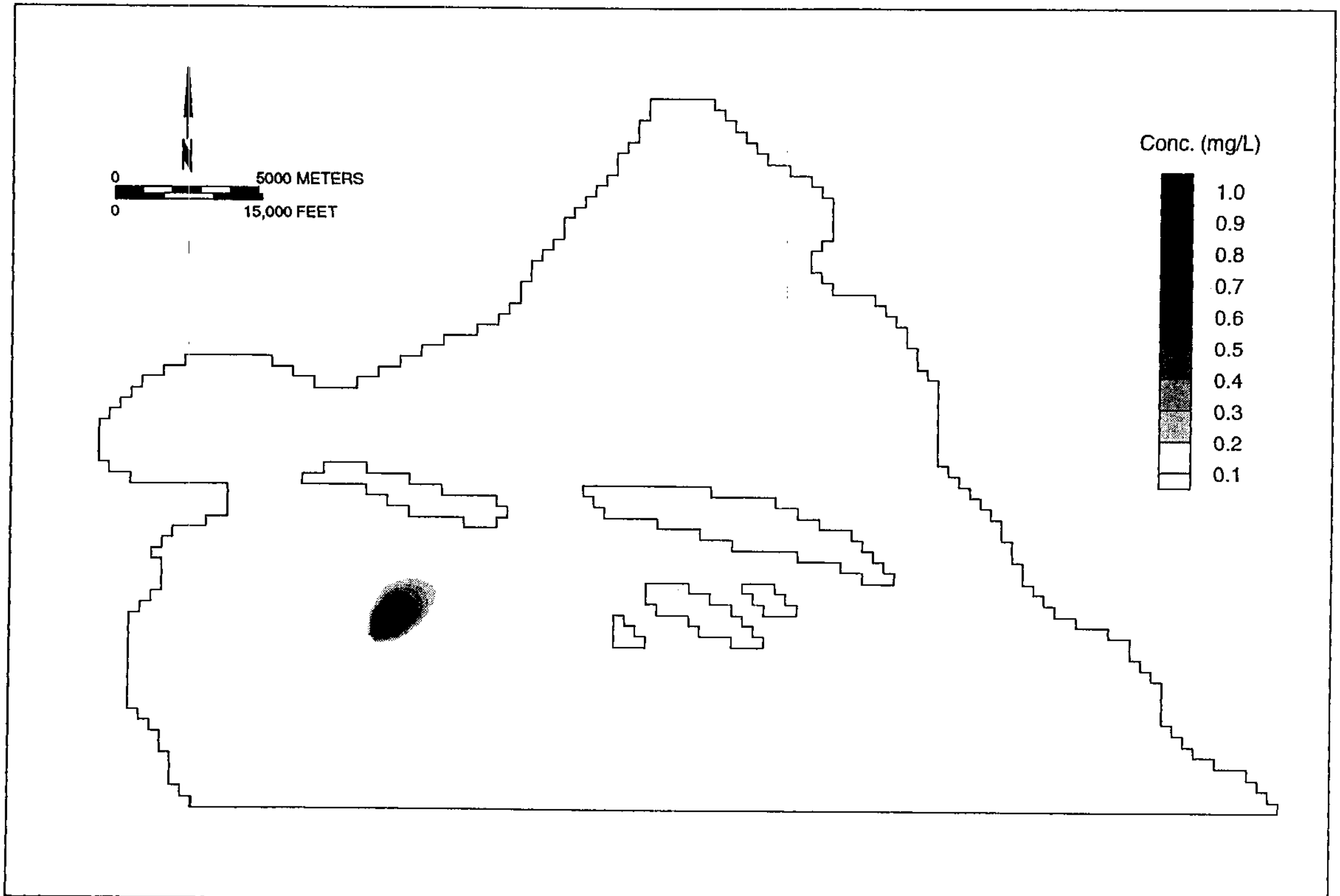

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Figure 9. Concentration Contours After 50 Years.

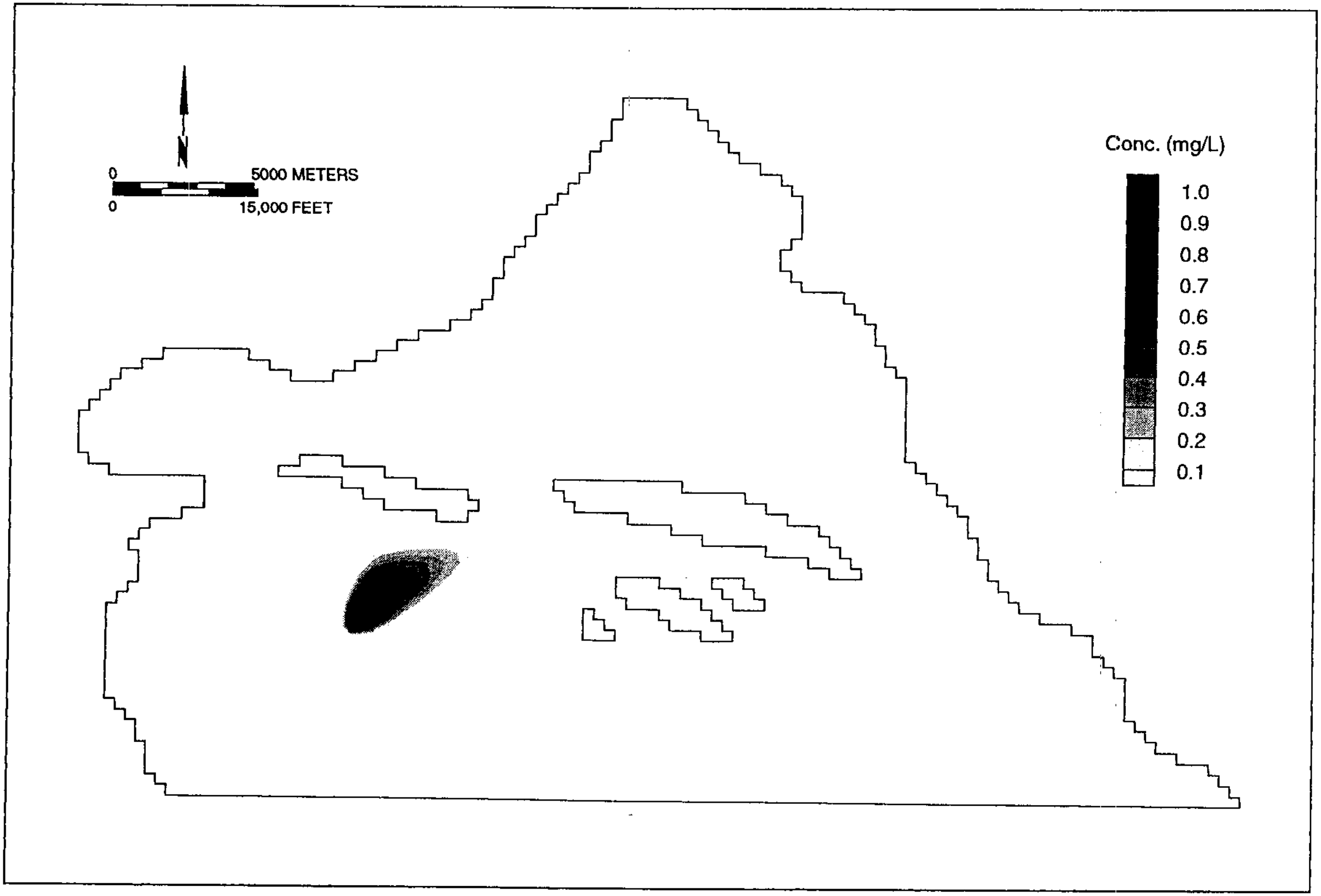

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Figure 10. Concentration Contours After 75 Years.

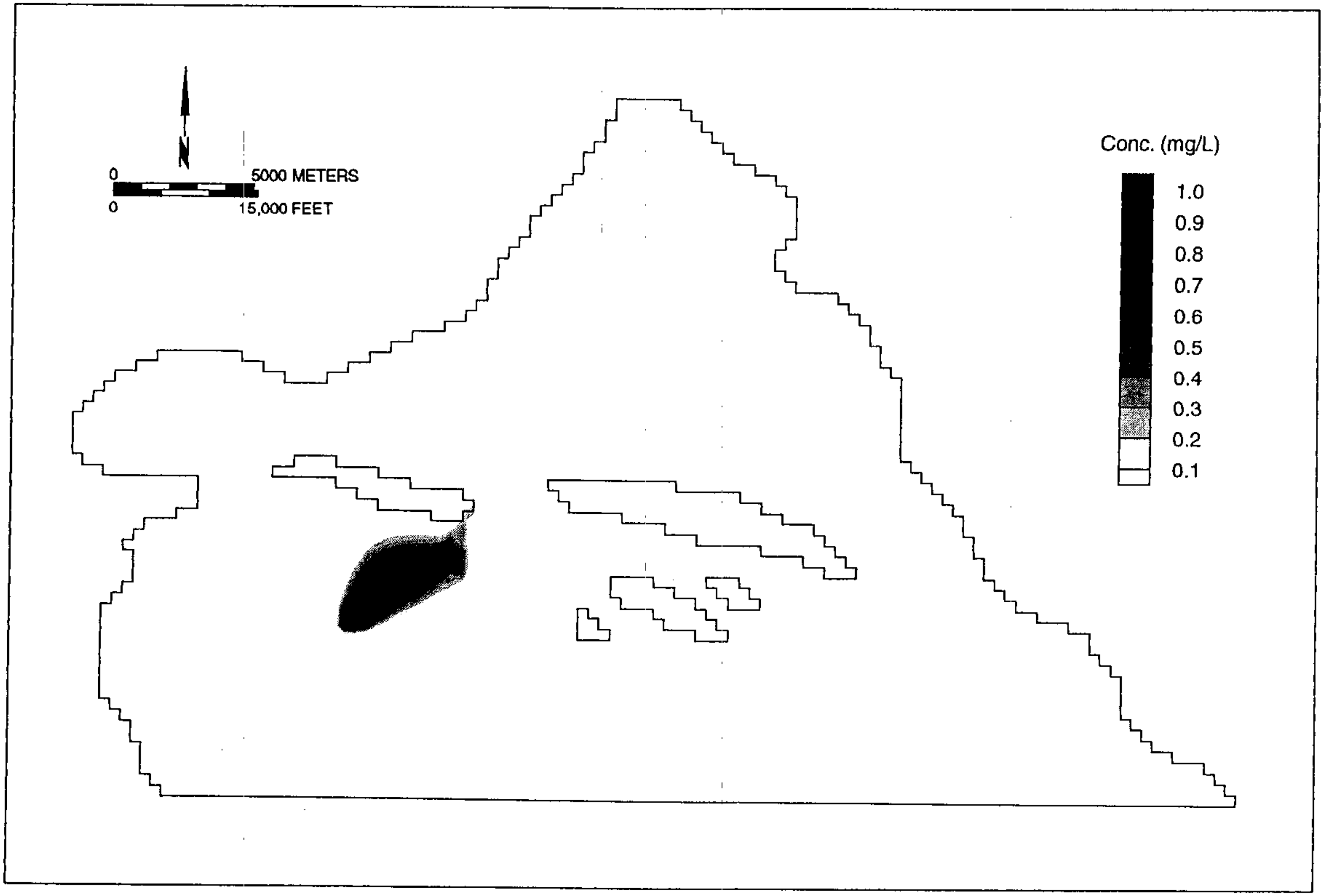

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Figure 11. Concentration Contours After 100 Years.

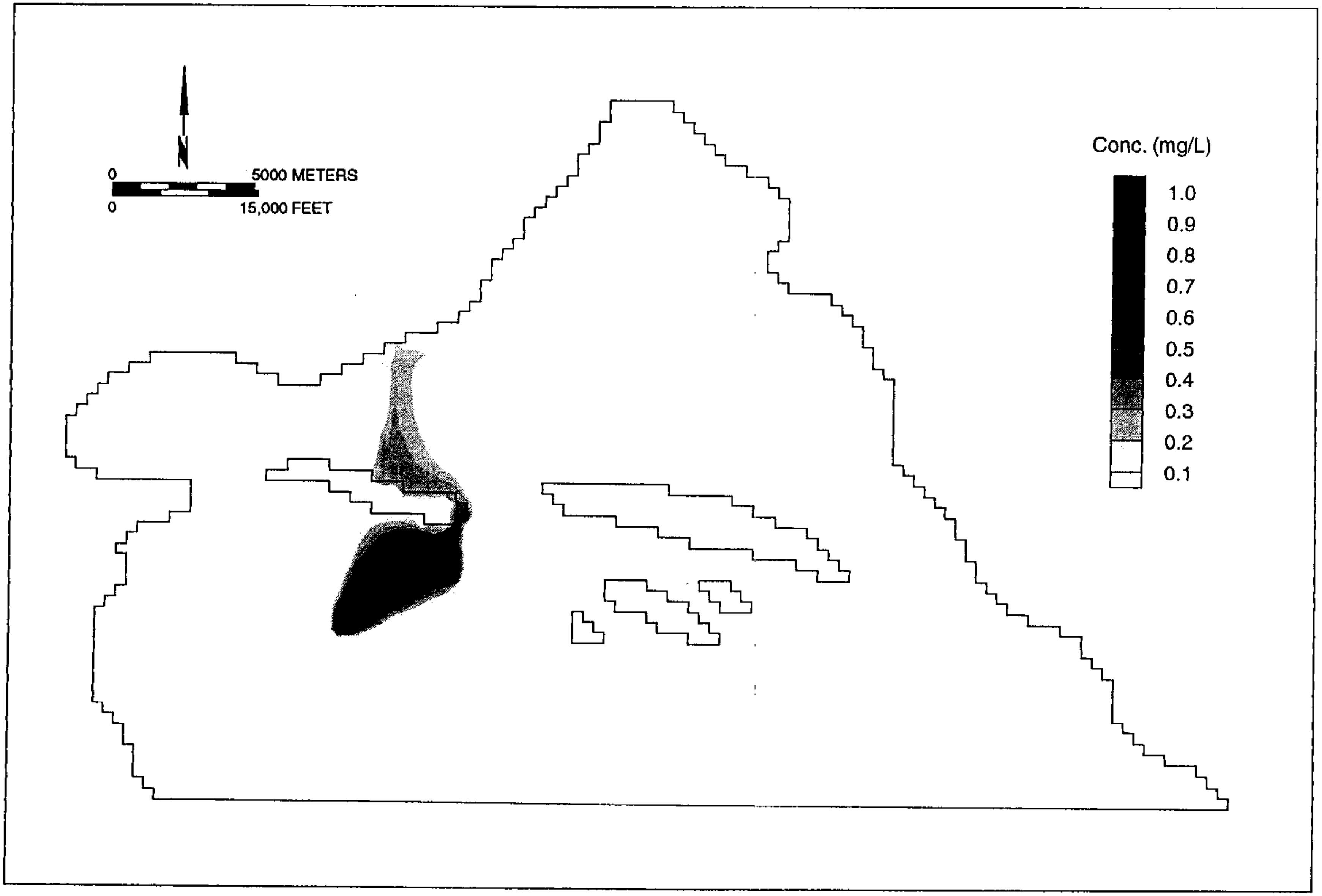

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Figure 12. Concentration Contours After 200 Years.

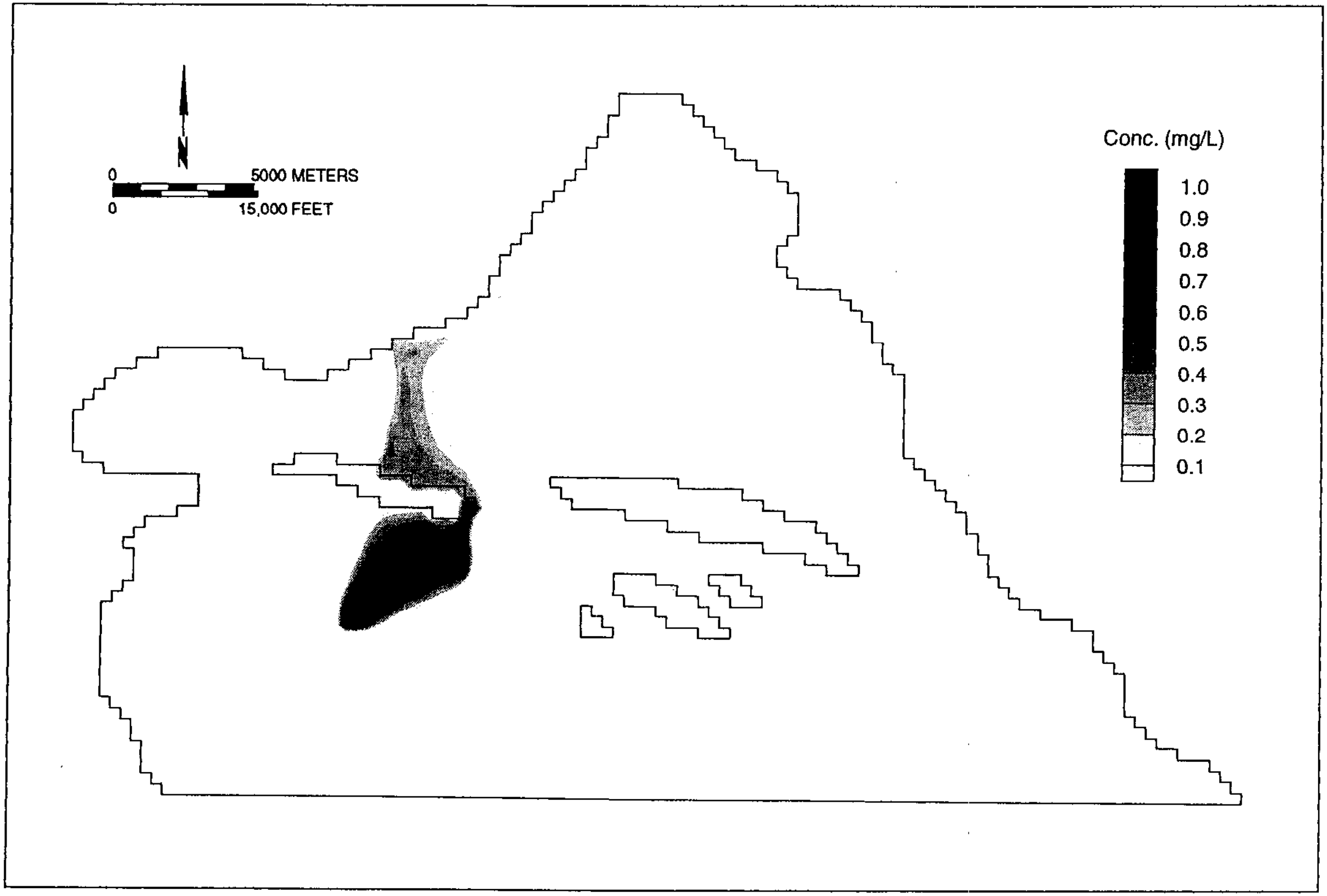

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Figure 13. Concentration Contours After 300 Years.

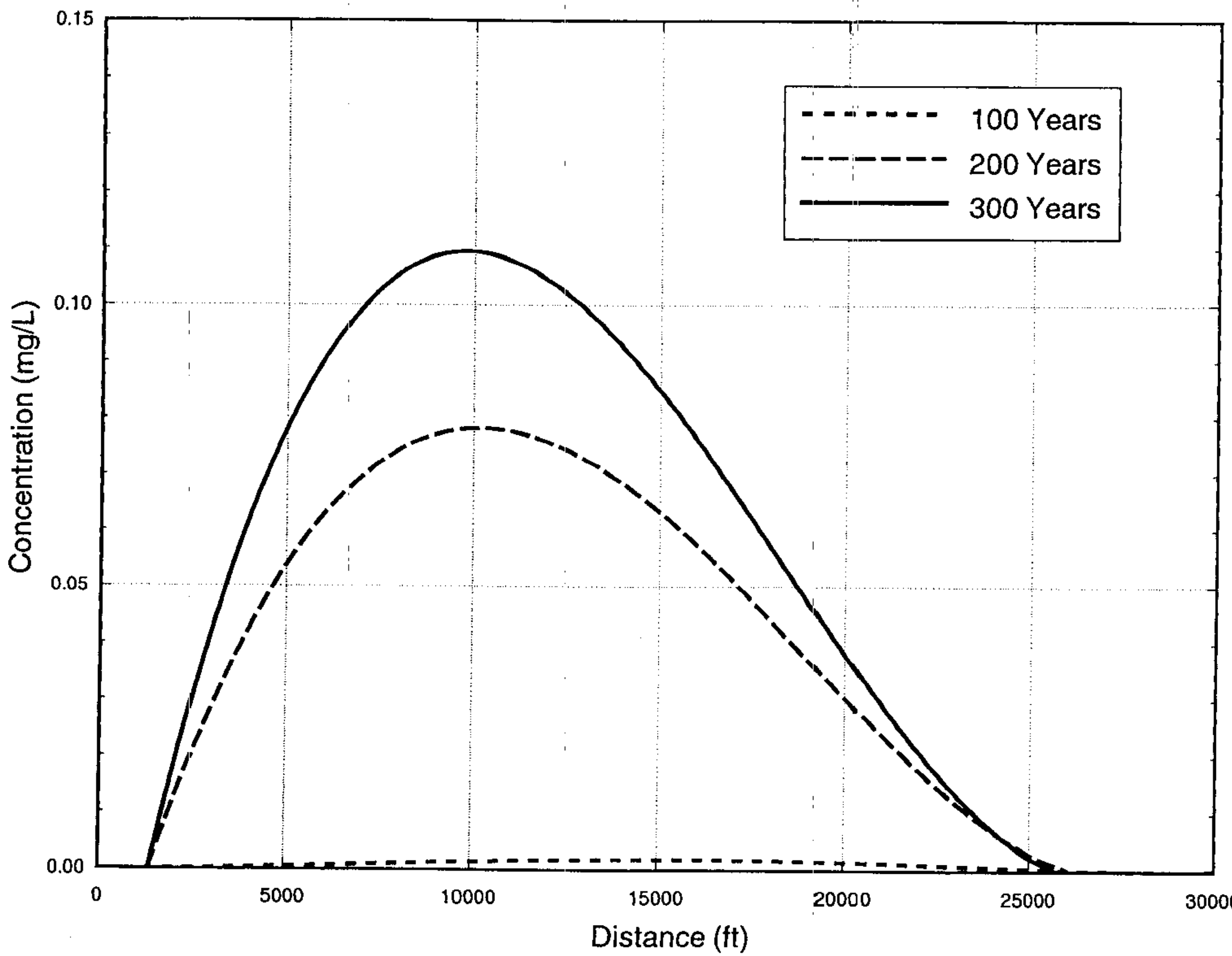

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Figure 14. Concentration Profiles at the Columbia River.

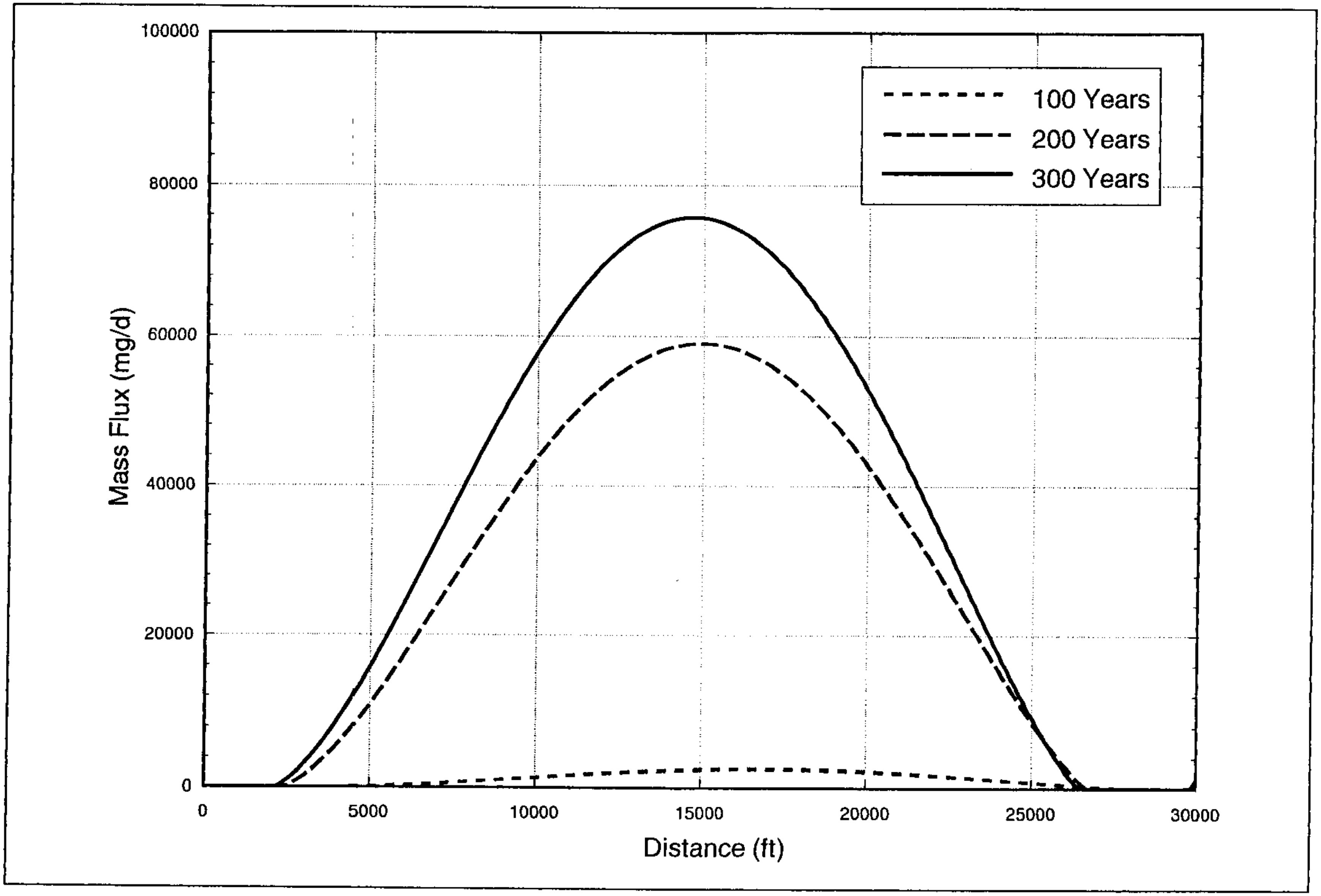

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Figure 15. Mass Flux Profiles at the Columbia River.

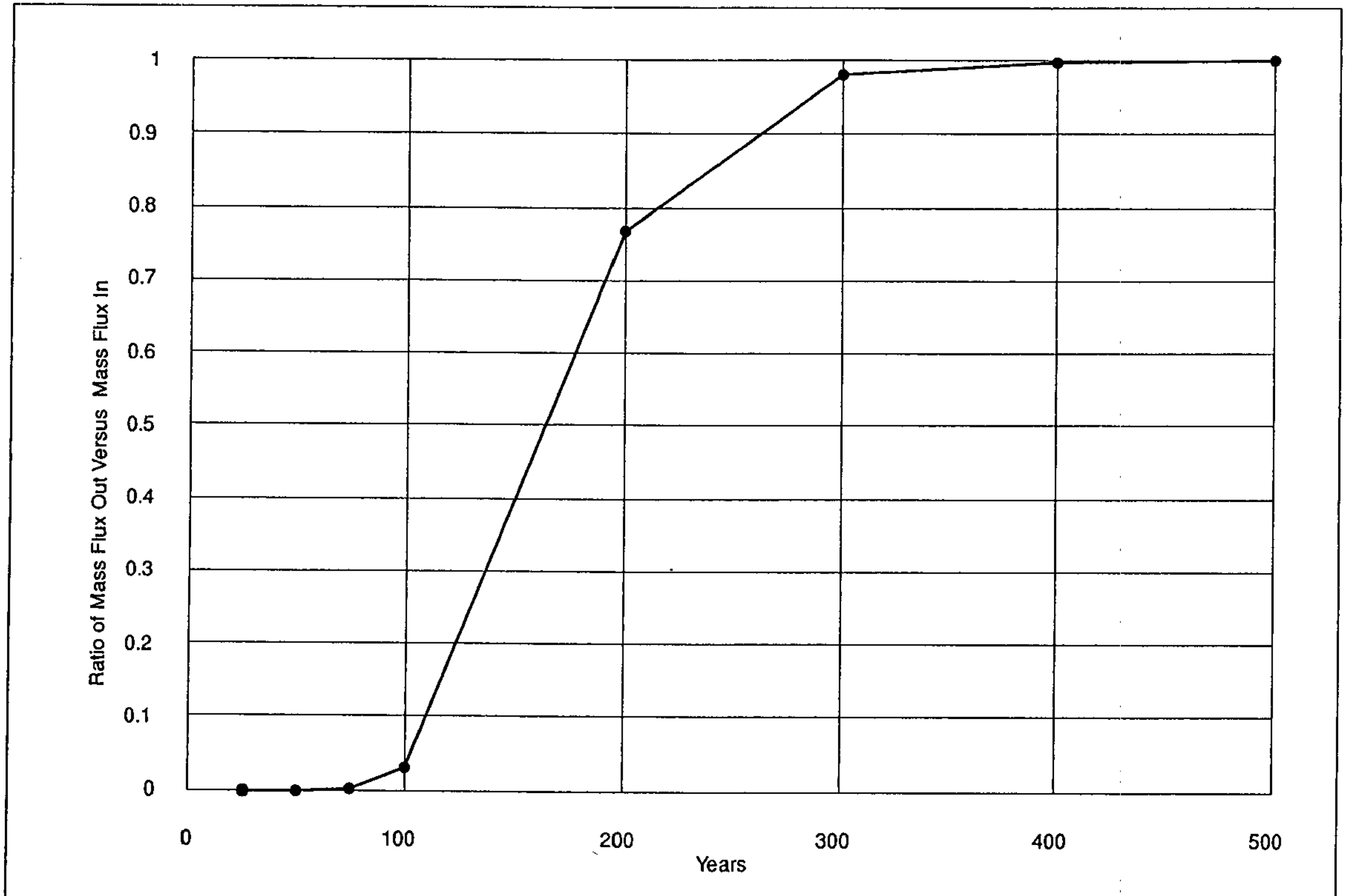

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Figure 16. Ratio of Mass Flux Leaving the Model Domain and Entering the Columbia River to Mass Flux Input to the Model.

Enclosure 2

HYDROGEOLOGIC DOCUMENTS RELATED TO THE 200 AREA EFFLUENT TREATMENT FACILITY AND THE STATE-APPROVED LAND DISPOSAL SITE

This table lists documents that were released in support of the Effluent Treatment Facility Project and the associated State-Approved Land Disposal Site (Project C-018H). On the following pages, each document is described in terms of the purpose of the document (why it was written), and its general content (what types of information it contains).

1	*Project C-018H Wastewater Engineering Alternatives Report--Supplementary Information on Disposal Engineered Structures*, WHC-SD-C018H-ER-003, Rev. 0
2	*Groundwater Quality Characteristics at Three Candidate Sites for the C-018H Soil Column Disposal Facility*, WHC-SD-EN-ES-013, 1991.
3	*Preliminary Site Evaluation Report for a Soil Column Disposal Site for the 242-A Evaporator and PUREX Plant Condensate Treatment Facility*, WHC-SD-EN-EE-002, 1990.
4	*Vadose Zone Flow and Transport Modelling: C-018H Soil Column Disposal Siting Evaluation*, Lu et. al., 1992
5	*Characterization Report, C-018H Soil Column Disposal Siting Evaluation*, WHC-SD-C018H-RPT-001, 1992.
6	*Travel Time and Groundwater Mounding Estimates for Alternative Soil Column disposal Sites, Hanford Site, Washington*, WHC-SD-EN-ES-021, 1992.
7	*Groundwater Mounding and Plume Migration Analyses for Candidate State-Approved Land Disposal Structures, Hanford Site, Washington*, WHC-SD-EN-ES-022, 1992.
8	*Characterization Regulatory Support Document, Project C-018H Soil Column Disposal Siting Evaluation*, WHC-SD-C018H-TI-001, 1993.
9	*Site Evaluation Report, C-018H Disposal Siting Evaluation*, WHC-SD-EN-ES-036, 1993
10	*Geohydrologic Evaluation for the 200 Area Effluent Treatment Facility State-Approved Land Disposal Site - Addendum to the WAC 173-240 Engineering Report*, WHC-SD-C018H-ER-004, 1993.
11	*Characterization Work Plan, C-018H Soil Column Disposal Siting Evaluation*, WHC-SD-EN-AP-041, Rev. 1b.
12	*Groundwater Monitoring Plan for the State-Approved Land Disposal Site (SALDS)*, WHC-SD-C018H-PLN-004, Rev. 0.

1 **PROJECT C-018H WASTEWATER ENGINEERING ALTERNATIVES REPORT--SUPPLEMENTARY INFORMATION ON DISPOSAL ENGINEERED STRUCTURES**
WHC-SD-C018H-ER-003, Rev. 0

__Purpose__ - This document provides justification for the selection method and identification for a preferred site for the disposal of effluent from the 200 Area effluent treatment facility (ETF). Contents of report are required to meet state WAC regulations and milestones pursuant to the TPA.

__Contents__ - Contents of this report include the selection method and identification of the site for disposal of the effluent from the ETF. Supplementary information that describes expected the constituent concentration, the design parameters of the selected disposal method/site, project schedule, and professional assessment. Appendix A lists requirements stipulated in the WAC 173-240-130, and Appendixes B-F are key documents that support this report.

2 **GROUNDWATER QUALITY CHARACTERIZATION AT THREE CANDIDATE SITES FOR THE C-018H SOIL COLUMN DISPOSAL FACILITY**
WHC-SD-EN-ES-013, Rev. 0
Appendix D to WHC-SD-C018H-ER-003

__Purpose__ - This document was written to provide groundwater quality information necessary to evaluate three candidate sites for the C-018H Soil Column Disposal Site.

__Contents__ - Technical data was compiled for use in evaluating groundwater quality and the impacts from various facilities on the three candidate sites. Tasks completed include the following:

- Evaluation of existing groundwater monitoring wells in the vicinity of each candidate site to determine their suitability for characterization and permitting activities
- Evaluation of the extent of groundwater contamination and presentation of groundwater quality data in the vicinity of each candidate site
- Estimation of the number and placement of additional characterization groundwater monitoring wells for each of the three candidate sites
- Determination of analytes of interest for these wells.

3 **PRELIMINARY SITE EVALUATION REPORT FOR A SOIL COLUMN DISPOSAL SITE FOR THE 242-A EVAPORATOR AND PUREX PLANT CONDENSATE TREATMENT FACILITY**
WHC-SD-EN-EE-002
Appendix B to WHC-SD-C018H-ER-003

__Purpose__ - The purpose of this site evaluation is the preliminary selection of candidate sites for a soils column disposal site for the 242-A evaporator and PUREX plant condensate treatment facility.

__Contents__ - The contents of this report contains site selection criteria and evaluation criteria that includes:

- Site background
- Determining criteria
- Engineering criteria
  - Health and Safety
  - Environmental impact
  - Operational impact
  - Land use
- Appendices (preliminary candidate site locations, groundwater travel time).

4 **VADOSE ZONE FLOW AND TRANSPORT MODELING: C-018H SOIL COLUMN DISPOSAL SITING EVALUATION**

__Purpose__ - The objectives of this modeling study are to determine the lateral extent of migration of the introduced tritium plume at the proposed soil column disposal facility. This information will be used to estimate if the plume from the disposal operations is likely to encroach on vadose zone contaminant plumes that result from other disposal facilities; and estimate what the tritium concentrations will be in the vadose zone and in the unconfined aquifer.

__Contents__ - This paper includes a site-specific flow and transport model and the results of numerical simulations used to investigate the impact of the proposed C-018H tritium disposal facility on the vadose zone in the 200 West area.

5 **CHARACTERIZATION REPORT, C-018H DISPOSAL SITING EVALUATION**
WHC-SD-C018H-RPT-001, Rev. 0

__Purpose__ - The purpose of this report summarizes data collected to evaluate the geohydrology of the soil column disposal site (SCDS).

__Contents__ - Contents of report include:

- Site stratigraphy
- Geophysical Logging
- Site Hydrology/chemistry
- Column Leach tests
- Applicable Appendixes.

6 **TRAVEL TIME AND GROUNDWATER MOUNDING ESTIMATES FOR ALTERNATIVE SOIL COLUMN DISPOSAL SITES HANFORD SITE, WASHINGTON WHC-SD-EN-ES-021, Rev. 0**

__Purpose__ - This report was written to estimate the rate of groundwater travel time to the Columbia River from three candidate sites for an effluent disposal facility. The effluent disposal facility would be used to dispose of tritium-bearing waste.

__Contents__ - This report contains a conceptual groundwater flow model to support consideration of the soil column disposal site. For this report, particular information concerning groundwater mounding was desired. As a result, simulations in this study explicitly included mass influx from the alternative facilities.

7 **GROUNDWATER MOUNDING AND PLUME MIGRATION ANALYSES FOR CANDIDATE SOIL COLUMN DISPOSAL SITES HANFORD SITE, WASHINGTON WHC-SD-EN-ES-022, Rev. 0**

Appendix C to WHC-SD-C018H-ER-001

__Purpose__ - Computer simulations were conducted to estimate the effects resulting from disposal of tritium-contaminated effluent to three candidate soil column disposal sites. The specific objectives of the study were to:

- Simulate the movement of tritium plumes in the groundwater and provide estimates of the tritium concentration in groundwater that would discharge to the Columbia River
- Provide estimates of the extent of groundwater mounding.

__Contents__ - A two-dimensional numerical model for groundwater flow and conservative solute transport has been developed for the Hanford Site representing the uppermost aquifer. This model is based on several previous modeling efforts and involves a refined analysis of groundwater mounding and tritium-plume migration from the three candidate sites.

8 **CHARACTERIZATION REGULATORY SUPPORT DOCUMENT, PROJECT C-018H SOIL COLUMN DISPOSAL SITING EVALUATION WHC-SD-C018H-TI-001, Rev. 0**

__Purpose__ - The purpose of this document is to summarize characterization information applicable to WAC 173-240-130, and Section J, item 2 of the Project C-018H State Waste Discharge Permit application. A state waste discharge permit must be approved before a state land disposal site can operate.

__Contents__ - The contents of this report contains site characterization data applicable to the above regulations which includes the following:

- Material between land surface and water table
- Depth to water table
- Groundwater quality
- Aquifer materials
- Groundwater movement
- Water balance analysis
- Impact of effluent plume on existing contamination
- Site-specific chemical and physical sample data
- Modeling results.

9 **SITE EVALUATION REPORT, C-018H DISPOSAL SITING EVALUATION WHC-SD-EN-ES-036 REV. 0**

__Purpose__ - This site evaluation report (SER) describes the evaluation process used to identify the best location to receive treated effluent from the 200 Area Effluent Treatment Facility (ETF). The intent of this SER is to meet the requirements of pertinent DOE and DOE-RL orders. Those orders include DOE-RL 4320-2C and DOE 6430.1a 0200. This document also partially fulfills the requirements for an engineering report (WAC 173-240-130).

__Contents__ - The objective of this SER is to identify the best location to receive treated effluent from the ETF. Information from studies and activities conducted for that purpose are presented. This report also presents a cost/benefit analysis for the three candidate sites.

10 **GEOHYDROLOGIC EVALUATION FOR THE 200 AREA EFFLUENT TREATMENT FACILITY STATE-APPROVED LAND DISPOSAL SITE - ADDENDUM TO WAC 173-240 ENGINEERING REPORT WHC-SD-C018H-ER-004, Rev. 0**

<u>Purpose</u>- This document was written to fulfill the Washington State requirement of providing a geohydrologic engineering evaluation for a proposed waste discharge site [WAC 173-240-130(2)(p)].

<u>Contents</u>- This report contains the field investigative findings and numerical modelling results for the proposed State-Approved Land Disposal Site (SALDS). Conclusions are drawn with respect to the geologic suitability of the site, and the hydrologic impacts and contaminant impacts of disposal. Details descriptions are presented for the regional and site geology, hydrology, and groundwater chemistry; the results of numerical vadose zone and groundwater transport models.

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11 **CHARACTERIZATION WORK PLAN, C-018H SOIL COLUMN DISPOSAL SITING EVALUATION WHC-SD-EN-AP-041, Rev. 1b**

<u>Purpose</u> - This work plan was written to guide field activities during characterization of candidate sites for the soil column disposal site in support of the 242-A Evaporator/PUREX Plant Condensate Treatment Facility, Project C-018H. The purpose of the characterization is to obtain information needed to complete the site selection and to support regulatory requirements.

<u>Contents</u> - The contents of this work plan include an initial evaluation of the sites to be characterized, the work plan rationale including data needs and characterization methods, and characterization tasks. Tasks include the following; (1) evaluation of existing data, (2) vadose and saturated zone soil sampling and analysis, (3) core archival, and (4) groundwater investigation. The work plan also discusses hydrologic modeling associated with characterization.

12 **GROUNDWATER MONITORING PLAN FOR THE STATE-APPROVED LAND DISPOSAL SITE (SALDS)**
WHC-SD-C018H-PLN-004, Rev. 0

Purpose- This document describes the on-going groundwater monitoring system that is being used to establish background groundwater quality, and the monitoring system that will be used to determine the impact of effluent disposal at the SALDS on the quality of groundwater in the uppermost aquifer after operation starts. The initial plan requirements were based on direction provided in the Resource Conservation and Recovery Act (RCRA) guidance for interim-status facilities and Washington State Administrative Code 173-200-080(3), (4), and (5), The plan will be modified as groundwater monitoring needs are better defined and negotiated with appropriate regulatory agencies.

Contents - This report contains an overview of the SALDS, the geology and hydrology of the area, the initial groundwater monitoring system, a detailed sampling and analysis plan, and an outline of a groundwater quality assessment (compliance) program (as required). This document does not provide a plan for institutional controls to track tritium beyond the SALDS.

MIGRATION OF NONDECAYING AND NONRETARDING CONSTITUENTS FROM THE STATE-APPROVED LAND DISPOSAL SITE, HANFORD SITE, WASHINGTON

Prepared for

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P.O. Box 1970
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Prepared by

Golder Associates Inc.
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WHC Contract No. MLW-SVV-073750
Task Order S-93-26
SAIC Project No. 01-1011-03-4546

January 19, 1994

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FIGURES

1.0 INTRODUCTION

A land disposal site north of the 200-West Area has been selected for disposal of tritium-bearing waste streams on the Hanford Site. The disposal site is called the Hanford State-Approved Land Disposal Site (SALDS). Its selection was based in part, upon the computer simulations of tritium plume migration summarized in the report *Groundwater Mounding and Plume Migration Analyses for Candidate Soil Column Disposal Sites, Hanford Site, Washington* (WHC 1991). That report is also presented as Appendix C of a Westinghouse Hanford Company wastewater engineering alternative report (WHC 1993).

The original siting analysis addressed only tritium migration, and did not consider the migration of other constituents that may be present in the waste. The objective of this study is to develop generic information on the migration of nondecaying, nonretarding chemical constituents that may be present with the tritium in the waste stream. The results are intended to provide, through the use of unit source concentrations, a means of conservatively estimating the concentrations and mass flux of such constituents in the groundwater prior to their release into the Columbia River. This study is considered an extension of the earlier study, and the same model has been used for both.

2.0 HANFORD SITE GROUNDWATER FLOW AND TRANSPORT MODEL

2.1 Model Development

The numerical modeling was performed using two two-dimensional finite element computer codes that are parts of the Golder Groundwater Computer Package (GGWP) (GAI 1993). The steady state groundwater flow field was simulated using the Aquifer Flow in Porous Media (AFPM) code, and the transient solute transport was simulated using the Solute Transport (SOLTR) code. The location of the disposal site within the region simulated by the model is shown in Figure 1. The finite element grid used in the modeling is shown in Figure 2, and is the same as in the previous study.

The model input parameters were unchanged from those used in the aforementioned study, with the following exceptions:

- The radioactive decay term, originally assumed for tritium in the previous model simulations, was set to zero to simulate a nondecaying constituent; and
- The concentration at the plume source in the groundwater, originally assumed for the expected actual tritium concentration, was set to the unit value of 1 mg/L.

Neither this nor the original modeling study considers retardation. The modifications made to the model will allow the migration of a generic, nondecaying and nonretarded chemical constituent to be estimated. The approach is conservative, and will tend to underestimate actual travel times and concentrations because most constituents are retarded by sorption/desorption and other chemical processes, and many will decay over time because of biological or radiological processes.

The approach is considered generic because the concentration of any specific constituent can be readily estimated from the modeling results if the actual source concentration is known. This is because of the linear relationship between the concentration and the other terms in the governing equation, when time-dependent decay is ignored. The concentration of any specific constituent is equal to its concentration at the source multiplied by the model-predicted concentration at any point in the flow field. The mass flux of any specific constituent may also be determined in a similar manner, provided that the volumetric discharge rate of the waste stream is the same as that assumed for the model. The modeling results are valid only for that discharge rate, and different plume characteristics and concentrations would be expected if the discharge rate varied.

2.2 Input Parameters and Assumptions

The development, validation, and application of the groundwater flow and solute transport models are described in detail in the report documenting the previous study (WHC 1991). Two-dimensional modeling cannot address the vertical concentration gradients that will be present within the aquifer. Because of this limitation and the generic nature of this study, average concentrations across the thickness of the aquifer are reported. In nature, however, higher concentrations would be expected in the upper part of the aquifer, and lower concentrations in the lower part. Because all aquifer water is considered to discharge into the Columbia River, the estimated chemical mass flux into the river will be essentially unaffected by ignoring the third dimension.

A continuous waste water discharge rate of 150 gallons per minute (gpm) was assumed in the modeling, and is the same as in the previous study (WHC 1991). As before, the disposal pond was assumed to be rectangular with dimensions of 220 ft by 100 ft. It was then assumed that as the effluent seeps through the unsaturated zone, it spreads with an angle from the vertical of 20°. As explained in the previous report, this value is consistent with data from a tank leak at the Hanford Site reported by Smoot et al. (1989). After migration through the approximately 220-foot thick unsaturated zone at the disposal site, the source area at the water table was assumed to be about 90,000 ft^2. The approach used to determine the size of the source at the water table is shown schematically in Figure 3, and the finite element grid in the immediate vicinity of the source is shown in Figure 4.

The effect of B-Pond was also included in the model to permit evaluation of plume development under current groundwater flow conditions. Inclusion of B-Pond is conservative, because the discharge from the pond increases hydraulic gradients through Gable Mountain Gap, and therefore increases groundwater flow rates toward the river. The assumed flux from B-Pond was 16.5 million gallons per day (mgd). Discharges into B-Pond strongly influence the direction and rate of groundwater movement in the Cold Creek Syncline, and different results would be expected from this modeling effort if discharges to B-Pond were significantly increased or decreased.

The hydrologic and transport properties of the geologic media were estimated from Hanford Site data, and from published data from other sites. Where uncertainties in parameter values were encountered, conservative estimates were made. Although dispersivity values are scale dependent, a constant dispersivity was in the model. To gain modeling accuracy at points of discharge along the Columbia River, the dispersivity used in the model was based on a large scale of interest (approximately 31,000 ft). The parameter values were the same as used in the previous study (WHC 1991), and are explained in detail in the aforementioned report.

Maps showing groundwater equipotentials in the simulated region and in the immediate vicinity of the disposal site are shown in Figures 5 and 6, respectively. A map of the predicted groundwater mound beneath the site under steady-state flow conditions is shown in Figure 7. Each of these figures is essentially the same as the parallel figure from the previous study (WHC 1991), and demonstrates the equivalency of the two studies.

3.0 LIMITATIONS OF THE MODELS

Any modeling effort requires simplification of the physical process being modeled, which introduces limitations into the model results. A detailed discussion of these limitations is presented in the previous report (WHC 1991), and they will only be highlighted here. None of these limitations are expected to change the conclusions regarding the principal objectives of this study.

- Two-dimensional modeling of a three-dimensional system cannot address effects resulting from vertical variations in conditions or processes. However, the results obtained from two-dimensional models are considered to be entirely adequate for the purposes of this study.

- Parameter values must be estimated if they are not available from site-specific measurements. Conservative estimates were used for this modeling such that constituent concentrations at the Columbia River would tend to be overestimated.

- If dispersivities representative of large scale distances are used, errors in plume shape are introduced near the source. Dispersivities used in this modeling are considered to be appropriate for studying constituent concentrations at the Columbia River; predicted plume geometries near the source are expected to be less accurate, but this will not affect the primary objectives of the study.

- The source term concentration and geometry is uncertain because of migration through the thick unsaturated zone. As a result, predicted plume geometries are expected to be less accurate near the source, but this will not affect the primary objectives of the study.

4.0 MODEL RESULTS

Model predictions of the progressive development of the plume beneath the disposal site are shown in Figures 8 through 13. These plumes depict the migration of a nondecaying, nonretarded chemical constituent released to the groundwater beneath the disposal site in a 150 gpm effluent stream at a concentration of 1 mg/L. The concentration values represent the average constituent concentration across the thickness of the aquifer. Only the northern part of the simulated region is shown. The irregularly shaped areas within the model domain represent subcrops of low permeability basalt bedrock that rise above the water table.

Figure 8 shows the predicted plume geometry 25 years after startup of effluent discharge. The plume has a regular, somewhat elliptical shape reflective of the fairly uniform groundwater flow field and transmissivity in this area. Figure 9 shows the plume geometry after 50 years. Here the movement toward Gable Mountain Gap is clearly evident. After 75 years, as shown in Figure 10, the plume is nearly to the gap and is just about to enter a higher transmissivity zone that passes through the gap. After 100 years, as shown in Figure 11, the leading edge of the plume has passed quickly through the gap and is curling around the north side of Gable Butte. This movement reflects the influence of B-Pond, which causes a significant groundwater flow through the gap that limits groundwater from the west side of the Site to the west side of the gap.

Figure 12 shows the predicted shape of the plume after 200 years. At this time the leading edge of the plume has reached the river. Additional modeling was conducted at 100-year intervals to 700 years. No significant changes were observed past 300 years, indicating that the plume had essentially reached steady state. Predicted groundwater concentration 300 years after disposal facility startup are shown in Figure 13.

Figure 14 is a plot of generic constituent concentrations in the groundwater at the river. Again, these are average concentrations across the thickness of the aquifer, based upon a unit source concentration, and are therefore normalized average concentrations for the groundwater discharging into the river. Actual concentrations may be higher in seeps along the river shore and lower in groundwater discharging into the river bottom sediments. The plot is drawn from the perspective of looking toward the river, thus the zero distance is on the upstream end of the profile. It should be noted that the graphical convention used to locate the zero point is different than in the corresponding figures of the earlier study (WHC 1991).

The groundwater concentrations are plotted in Figure 14 against model boundary distances for time periods of 100, 200, and 300 years. The curves shown in the figure represent the best fit fifth-order polynomial regression to the raw model output data. A regression curve was used to smooth the high frequency variations in the model output resulting from boundary effects, and thereby facilitate interpretation of the results. At 100 years, the model predicts concentrations that are near zero, and are too low to show up on the plume map in Figure 11. At 200 years, the concentrations have increased substantially, and the downriver elongation of the plume is evident. As the plume approaches steady state, the primary change is in the peak concentration and little additional plume spreading is observed. After 300 years, the plume is essentially at steady state and further increases in peak concentrations were not observed in the modeling.

The generic mass flux discharge of the constituent is plotted in Figure 15 against model boundary distances for the same time periods as in the previous figures. Again, the plotted curves represent the best fit fifth-order polynomial regression to the raw model output data. After 100 years, the mass flux discharge into the river is estimated to be very low. After 200 years, the mass flux has increased significantly and is close to steady state. After 300 years, the plume is essentially at steady state and further significant increases in mass flux were not predicted.

5.0 EVALUATION OF RESULTS

Because a unit source concentration of 1 mg/L was used in the model, the concentration of any specific chemical constituent in the groundwater along the river can be estimated by multiplying the normalized concentration shown in Figure 14 by the actual concentration in milligrams per liter of that constituent in the waste effluent. In interpreting the figure, the results shown are not intended to present a high resolution prediction of groundwater concentrations along the river, but instead have been generalized to identify trends. The distances shown in Figure 14 are model boundary distances. Because of the right angle steps in the model boundary, the cumulative distance along which discharges to the river are predicted is longer than the actual river length in this area. It may be concluded from Figure 14 that the peak constituent concentration along a 2-mile stretch of river is predicted to be close to zero after 100 years, about 7% to 8% of the source concentration after 200 years, and reach steady state at about 11% of the source concentration after 300 years. In reality, the disposal facility and its source processes may not operate for even 100 years, in which case the average concentration at the river would peak at less than the steady state value, and then decline over time to zero.

The mass flux is equal to the concentrations in Figure 14 multiplied by the volumetric groundwater flow rates entering the Columbia River from the associated boundary elements in the model. The mass flux of any specific chemical may therefore be estimated by multiplying the normalized mass flux shown in Figure 15 by the actual concentration in milligrams per liter of that constituent in the waste effluent. This relationship will be valid so long as the effluent discharge rate at the source remains approximately 150 gpm. Again, the results should be considered generally indicative of the type of mass flux distribution that should be expected, but not of the localized effects of specific higher or lower transmissivity zones that may be present.

The areas under the curves in Figure 15 may be used to provide an estimate of the total mass flux entering the river from the disposal site. Figure 16 shows a plot of these values, normalized by dividing by the constant mass flux being discharged at the disposal site. At time periods of less than 100 years, this ratio is near zero, indicating essentially no discharge into the river. After 100 years, this ratio is perceptibly greater than zero, but is still small. After 200 years the ratio is approximately 75%, indicating that the rate of discharge into the river is about 75% of the constant mass flux being discharged at the disposal site. After 300 years this ratio is about 98%, and after 400 years it is essentially 100% and is clearly at steady state. Thus after 400 years, the rate of chemical discharge into the river is equal to the rate of discharge at the disposal site. Again, these relations are valid only for a 150 gpm effluent discharge rate at the source.

The results of this study can be used to conservatively estimate the concentrations and mass flux of nondecaying, nonretarding chemical constituents entering the Columbia River from a 150 gpm waste stream discharged at the SALDS facility. It is important to recognize that a number of conservative and simplifying assumptions have been used in this study that will tend to overestimate the actual concentration and mass flux values that would occur. The more important of these assumptions are as follows:

- an infinite facility lifetime,
- no saturated zone retardation,
- an infinite B-Pond lifetime,
- no unsaturated zone retardation,
- no biological decay of organics, and
- lower transverse and higher longitudinal dispersivity values.

If estimates based on this study are found to be unacceptably high, a more refined analysis may be appropriate to determine if the higher concentrations and fluxes are simply artifacts of the analytical approach, and would not actually be expected to occur. In performing a refined analysis, the following modifications could be considered and would be expected to have a significant effect on the results obtained.

- Remove B-Pond discharges from the model. It is understood that use of B-Pond is planned to be discontinued within the next ten years. This would be expected to reduce the groundwater flow velocity toward the river and permit a wider dispersion of the plume in the area north of Gable Mountain Gap.

- Incorporate the expected SALDS facility lifetime into the model. This would limit the lifetime of the plume and provide a better estimate of the maximum concentrations and fluxes to be expected at the river.

- Incorporate a conservative retardation factor into the model. This would better reflect the migration rates of actual chemicals, and would increase the travel time to the river.

6.0 REFERENCES

GAI, 1993, *Golder Groundwater Package, User and Theory Manuals,* Golder Associates Inc., Redmond, Washington.

Smoot, J.L., J.E. Szecsody, B. Sagar, G.W. Gee, and C.T. Kincaid (1989), *Simulations of Infiltration of Meteoric Water and Contaminant Plume Movement in the Vadose Zone at Single-Shell Tank 241-T-106 at the Hanford Site,* WHC-EP-0332, Westinghouse Hanford Company, Richland, Washington.

WHC, 1991, *Groundwater Mounding and Plume Migration Analyses for Candidate Soil Column Disposal Sites, Hanford Site, Washington,* WHC-MR-0276, Westinghouse Hanford Company, Richland, Washington.

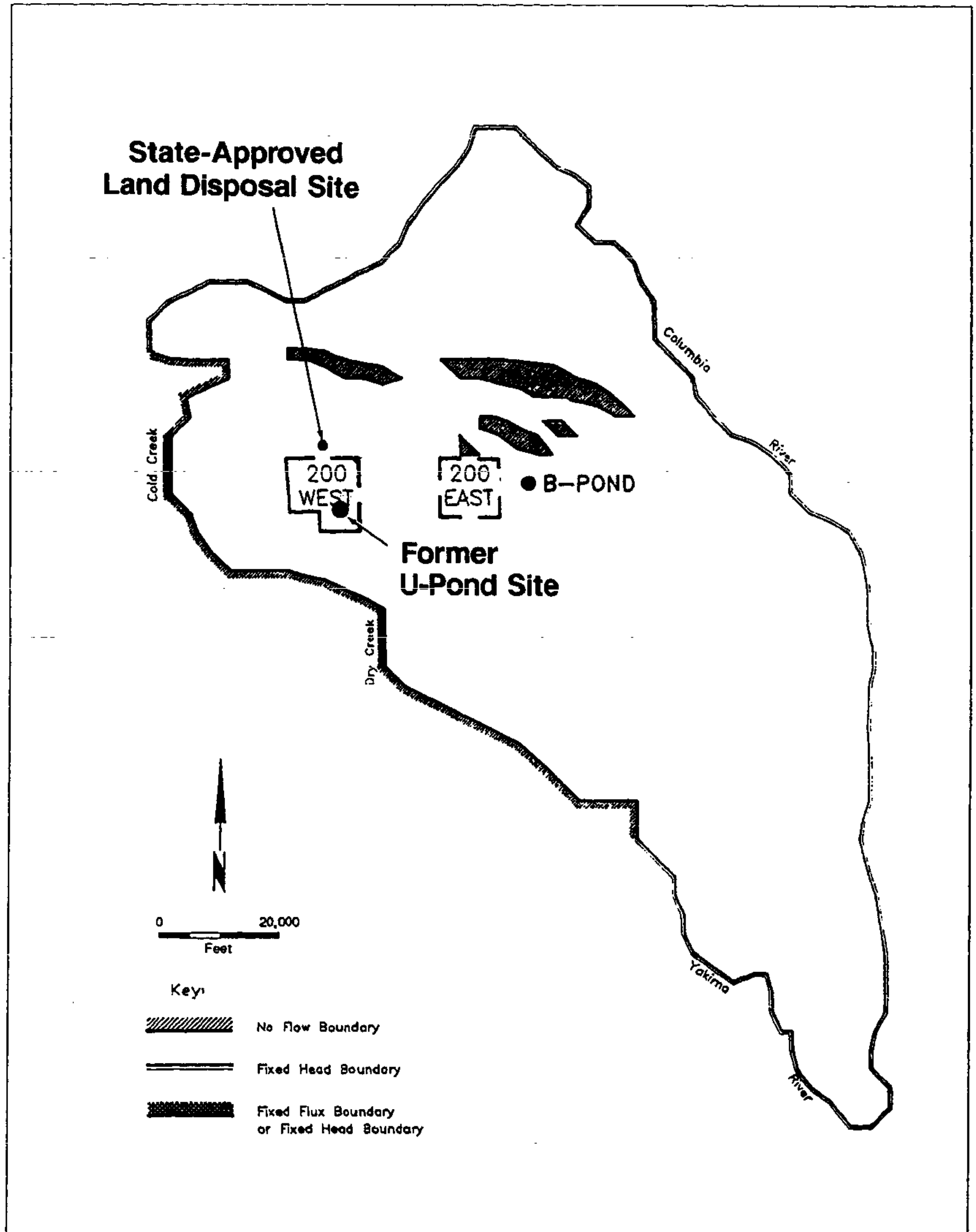

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Figure 1. Simulated Region.

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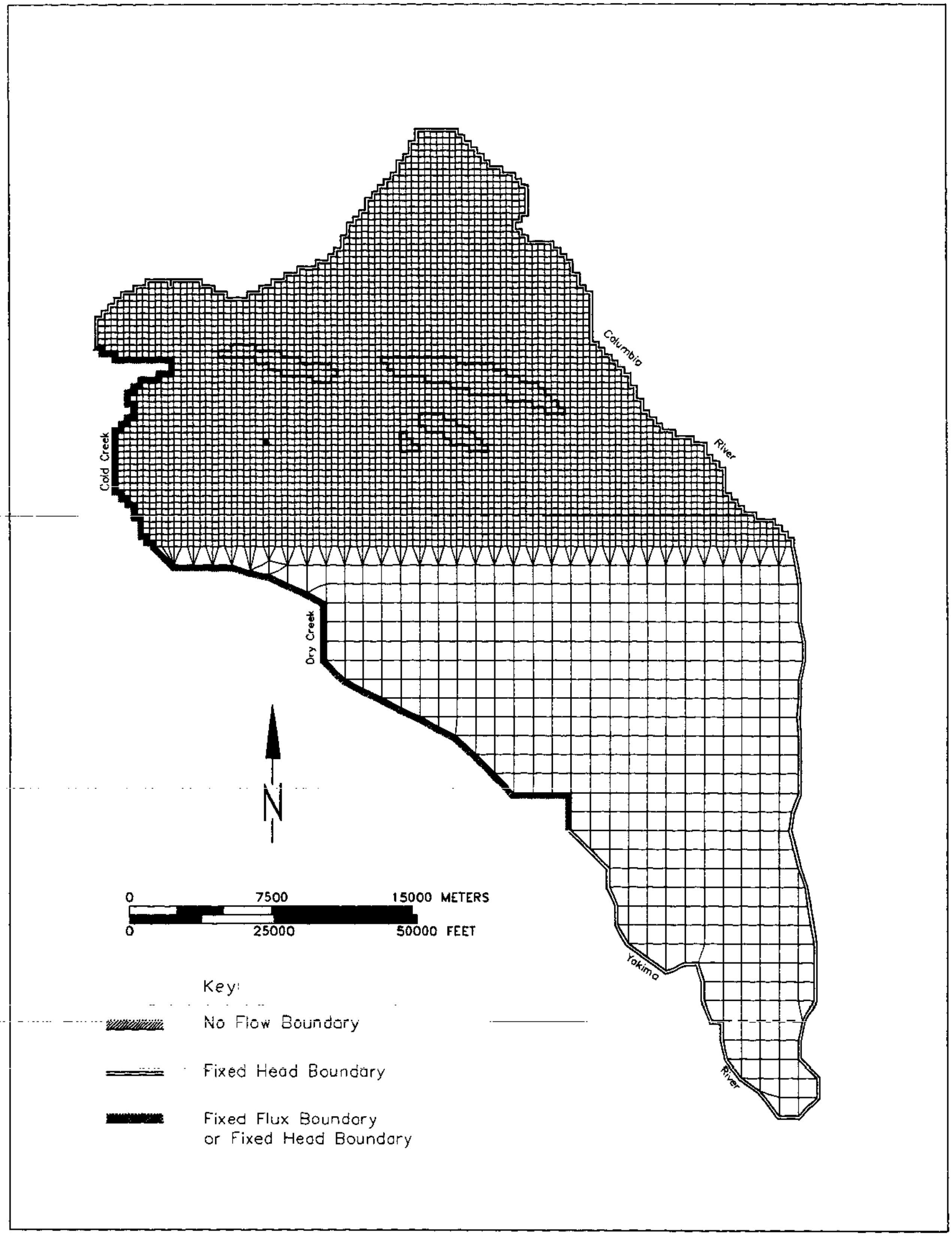

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Figure 2. Finite Element Grid.

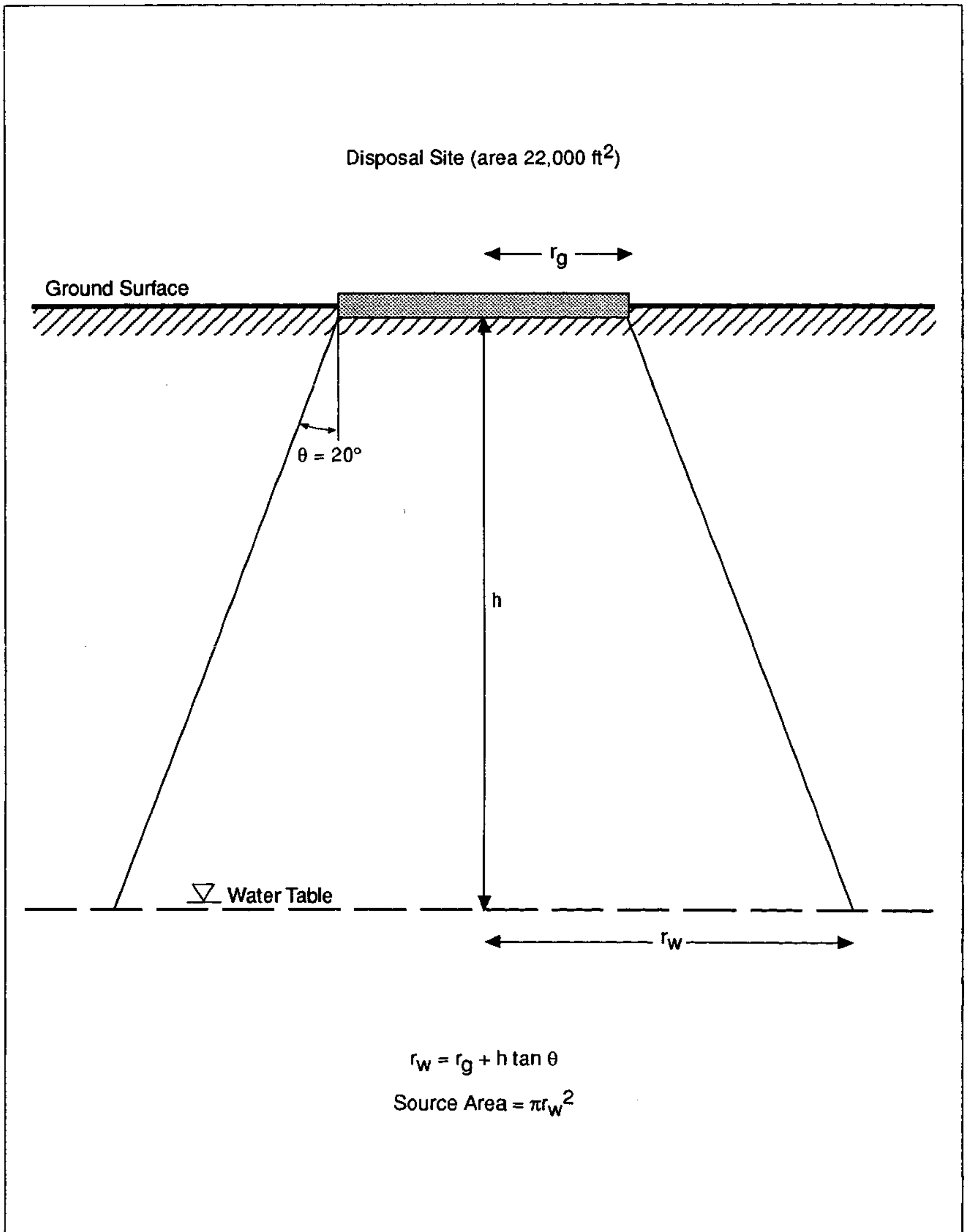

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Figure 3. Source Representation.

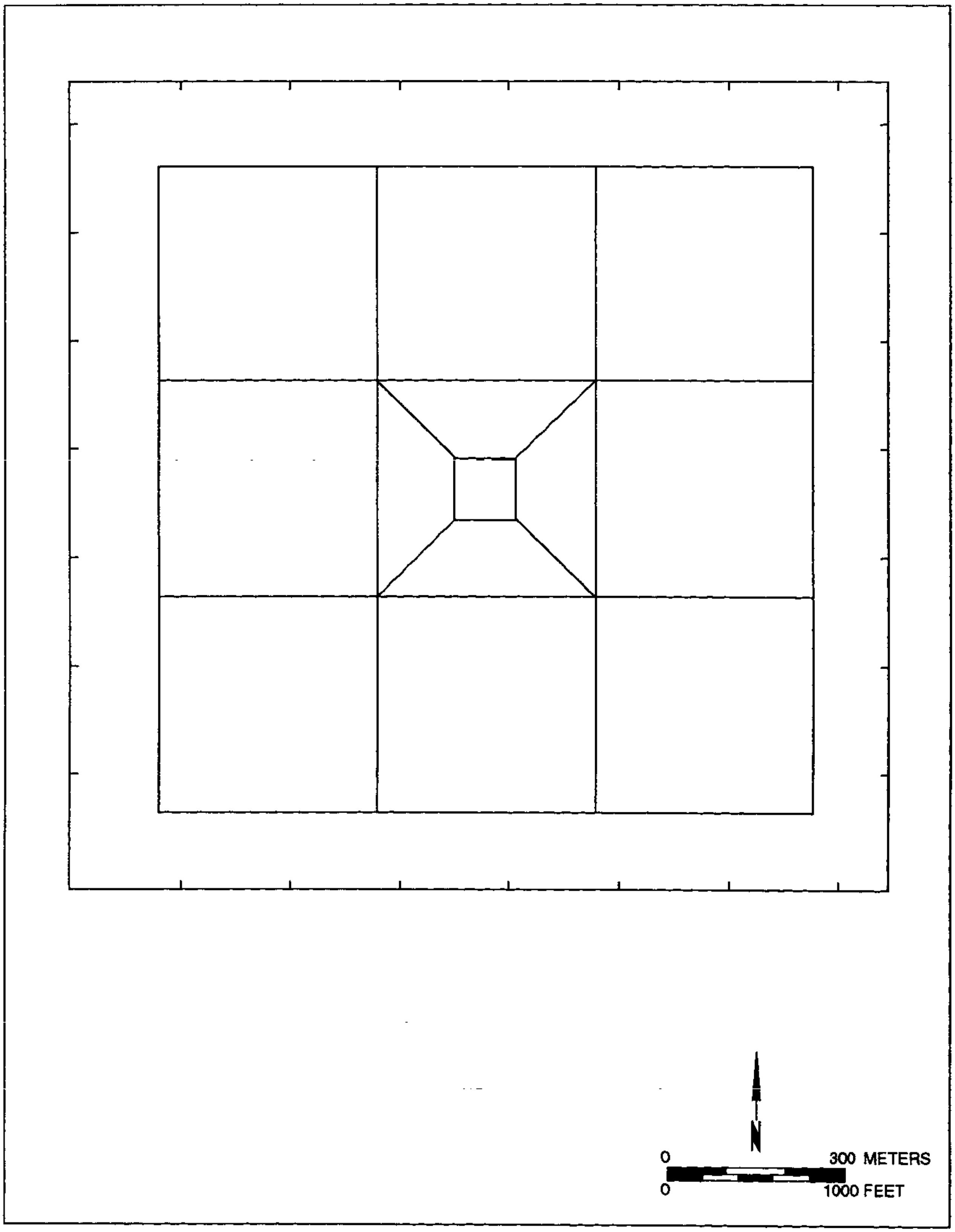

Figure 4. SALDS Discretization.

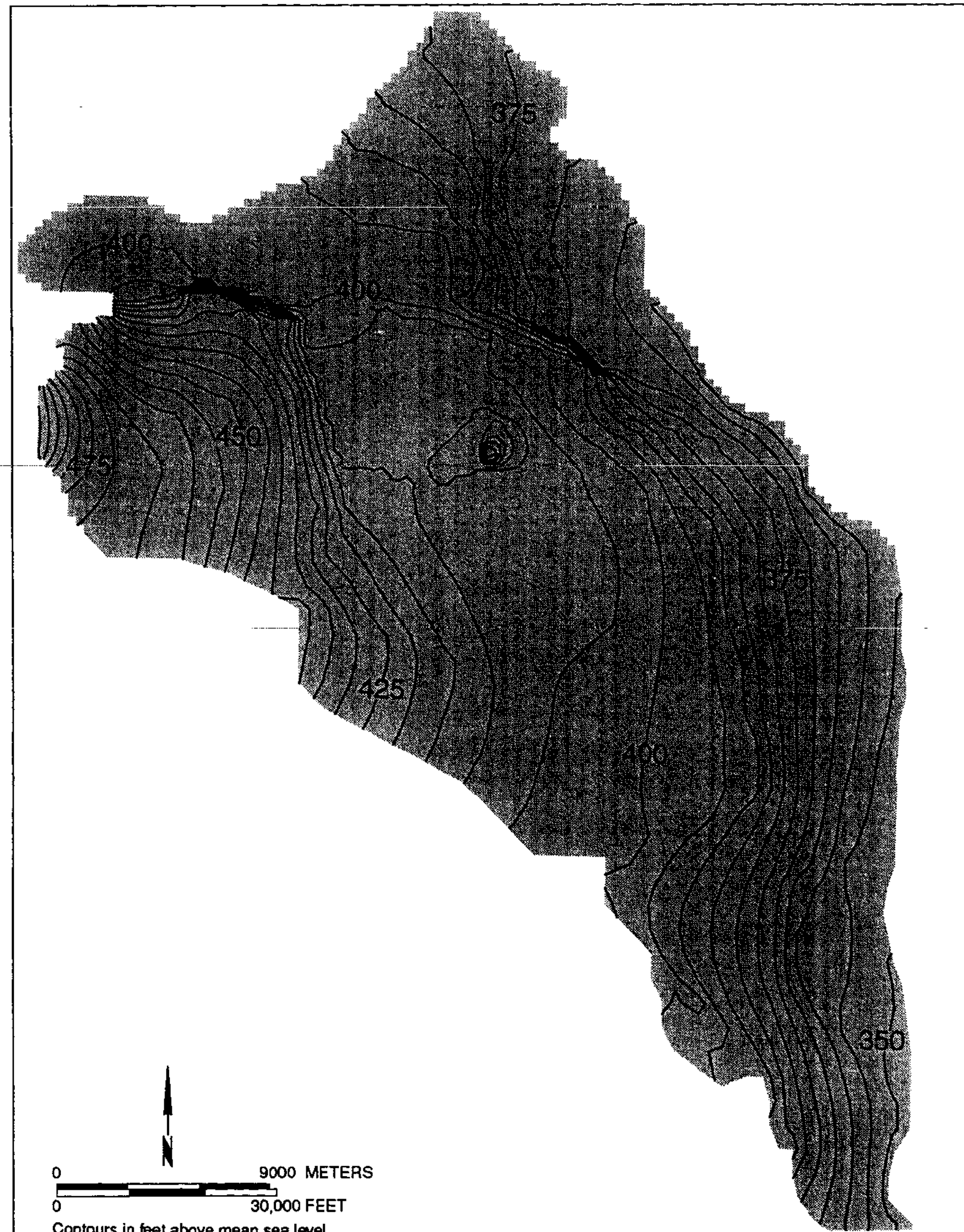

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Figure 5. Equipotentials with Disposal at SALDS.

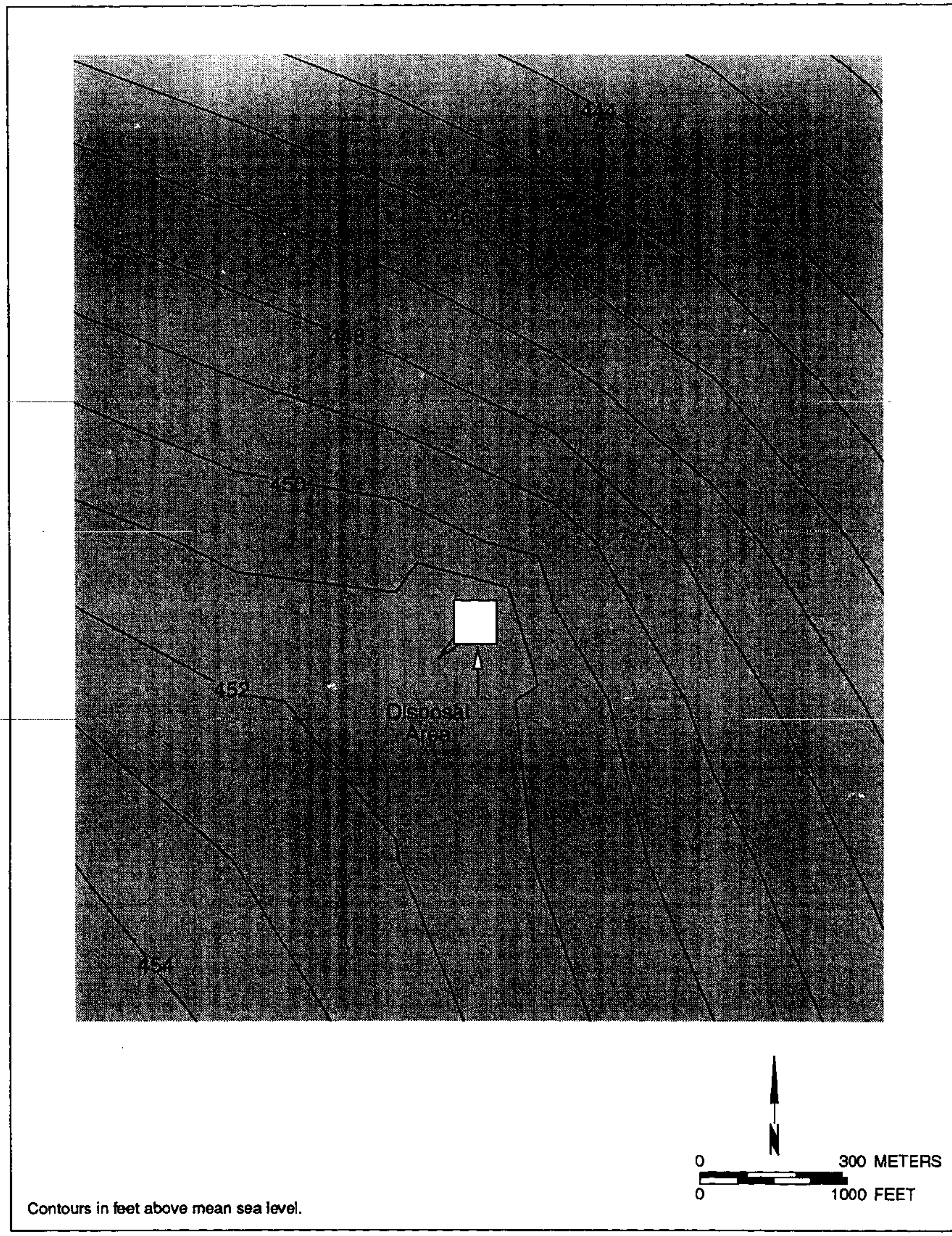

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Figure 6. Equipotentials Near SALDS.

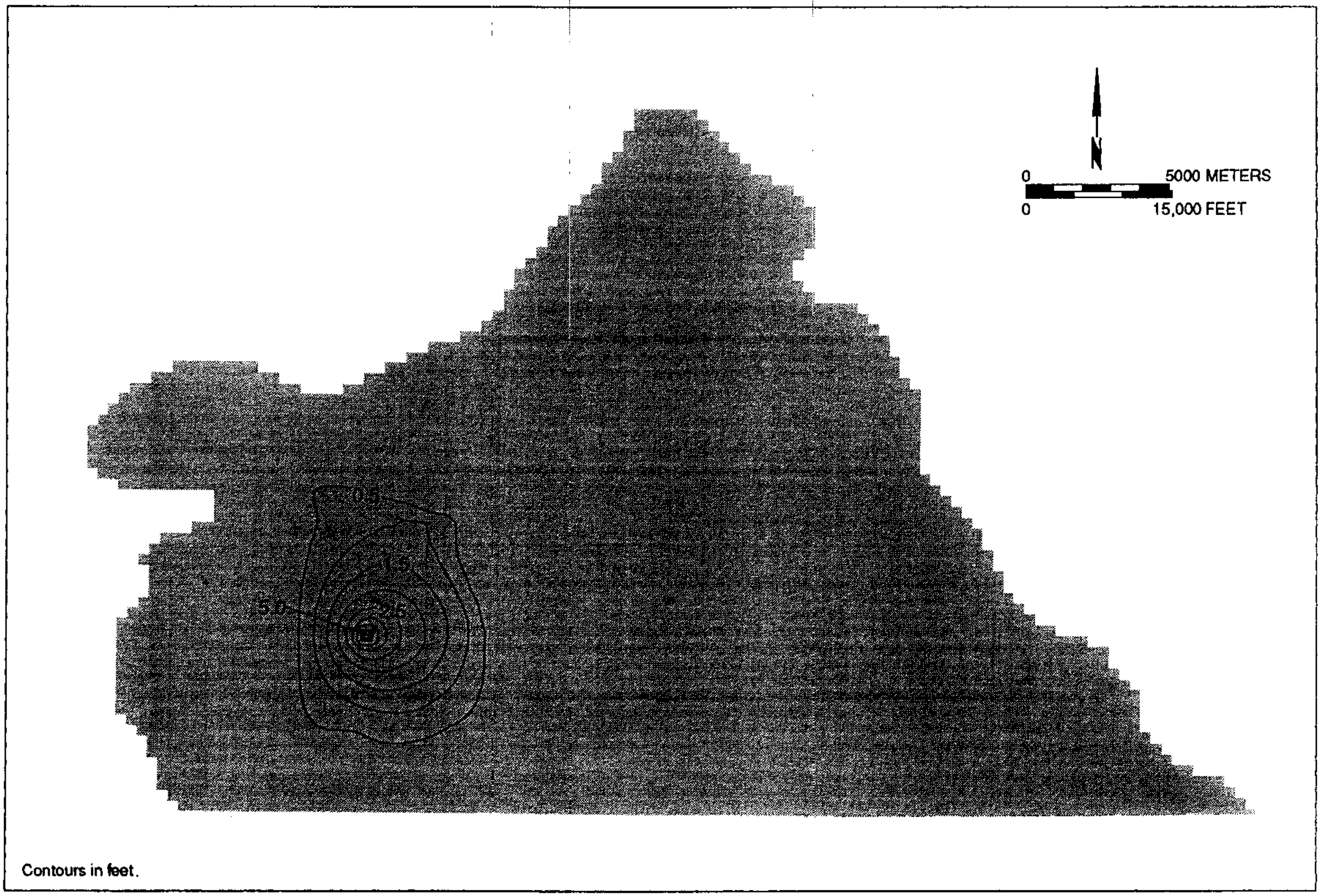

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Figure 7. Mound Formed Around SALDS.

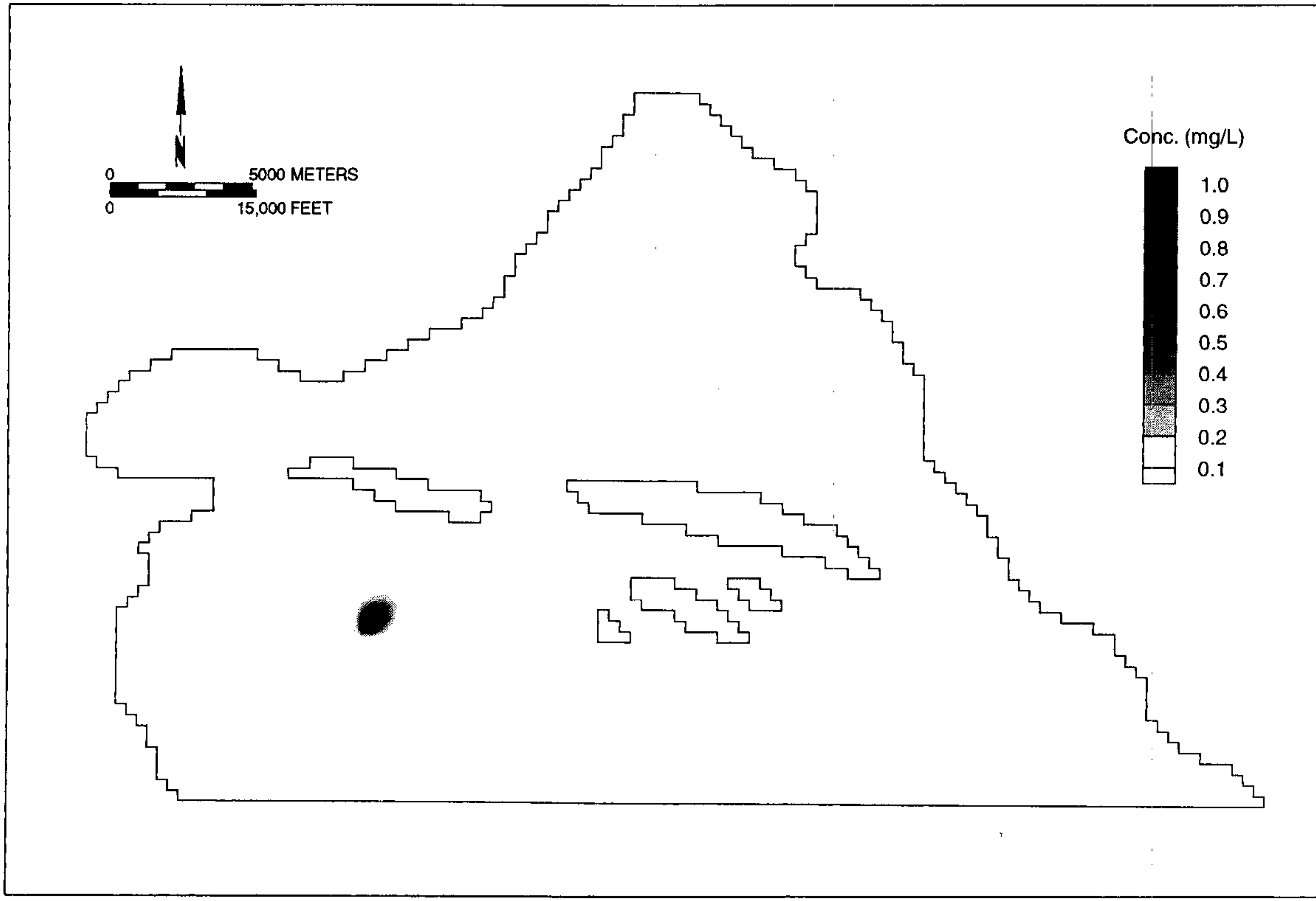

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Figure 8. Concentration Contours After 25 Years.

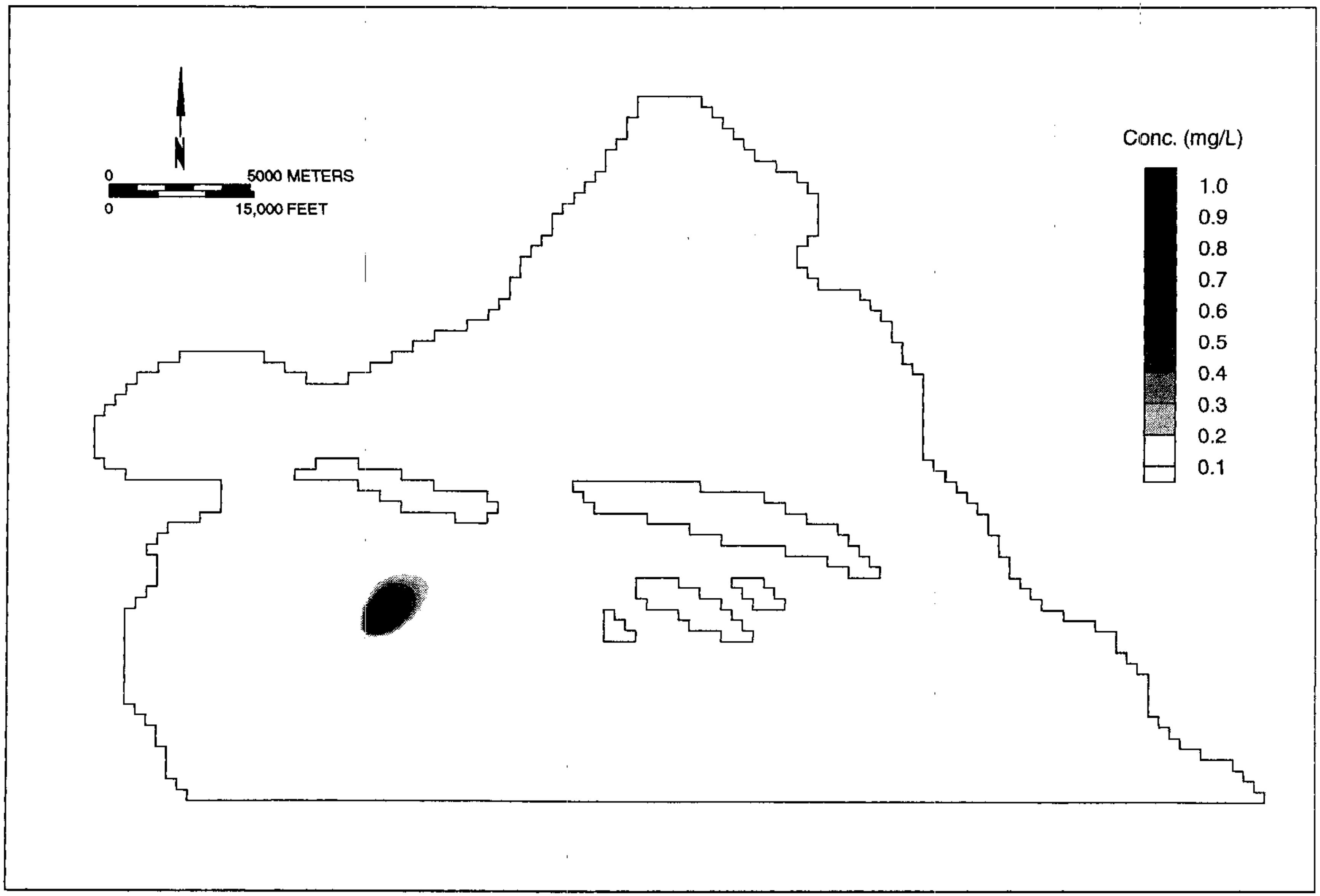

Figure 9. Concentration Contours After 50 Years.

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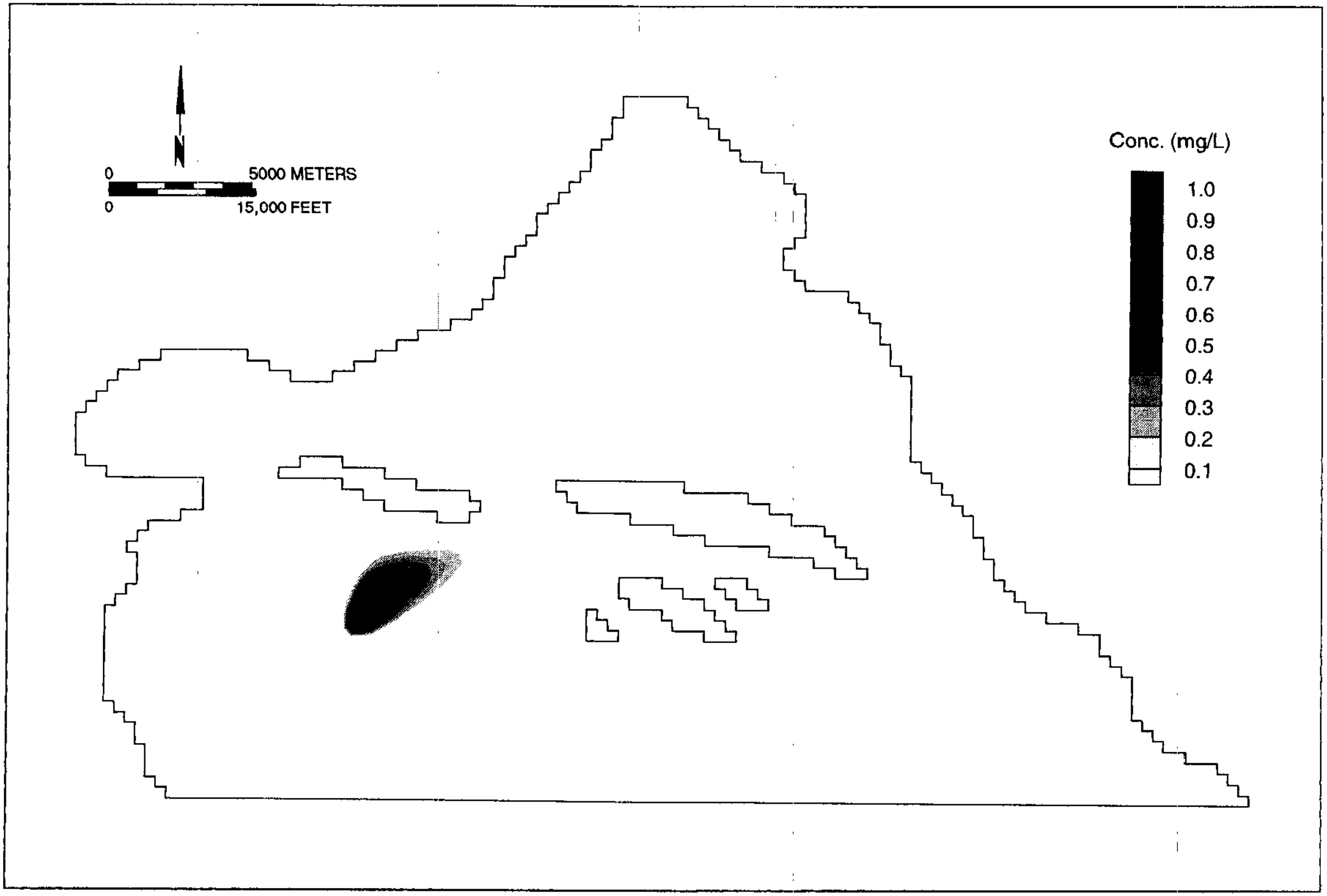

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Figure 10. Concentration Contours After 75 Years.

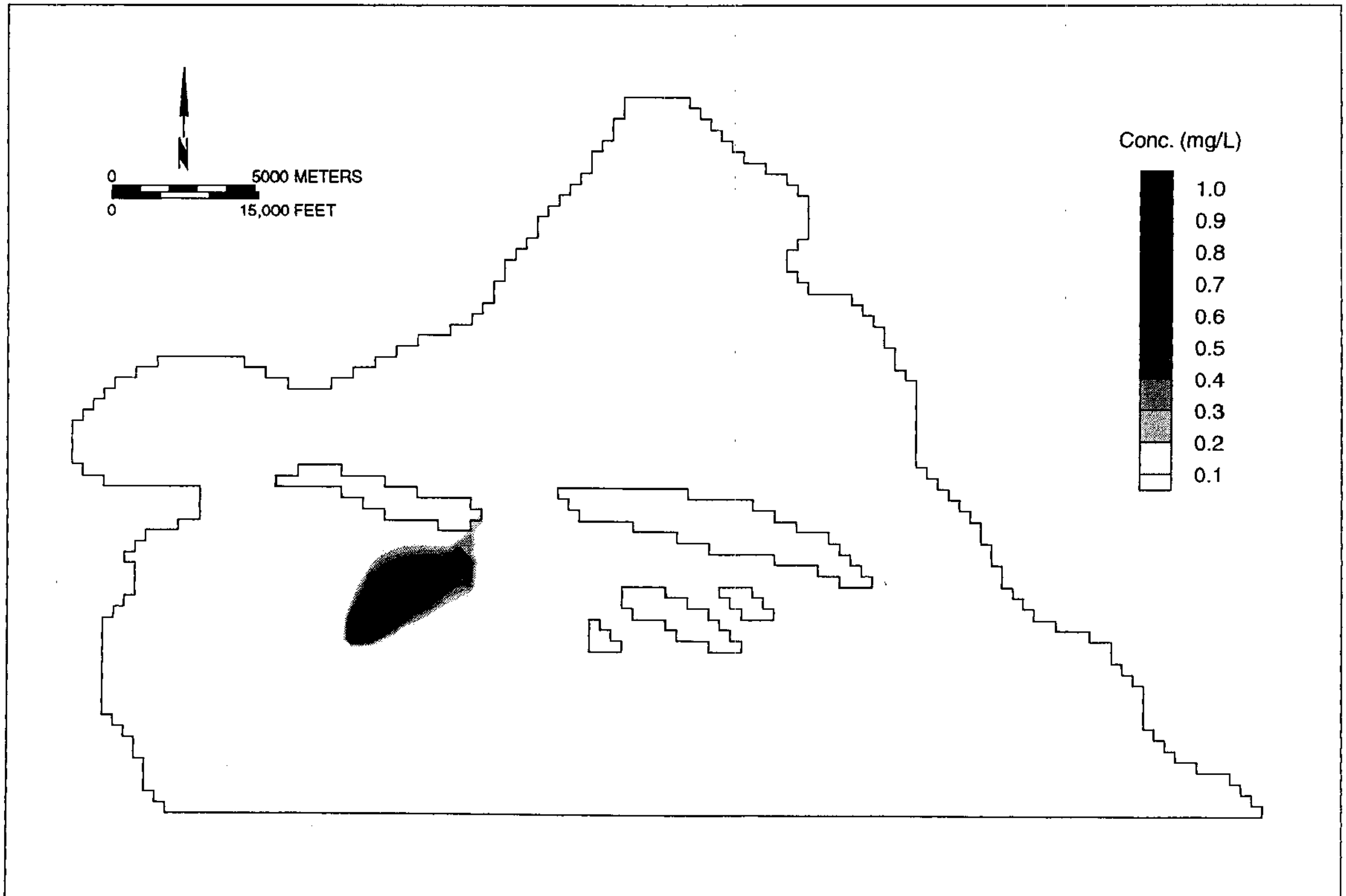

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Figure 11. Concentration Contours After 100 Years.

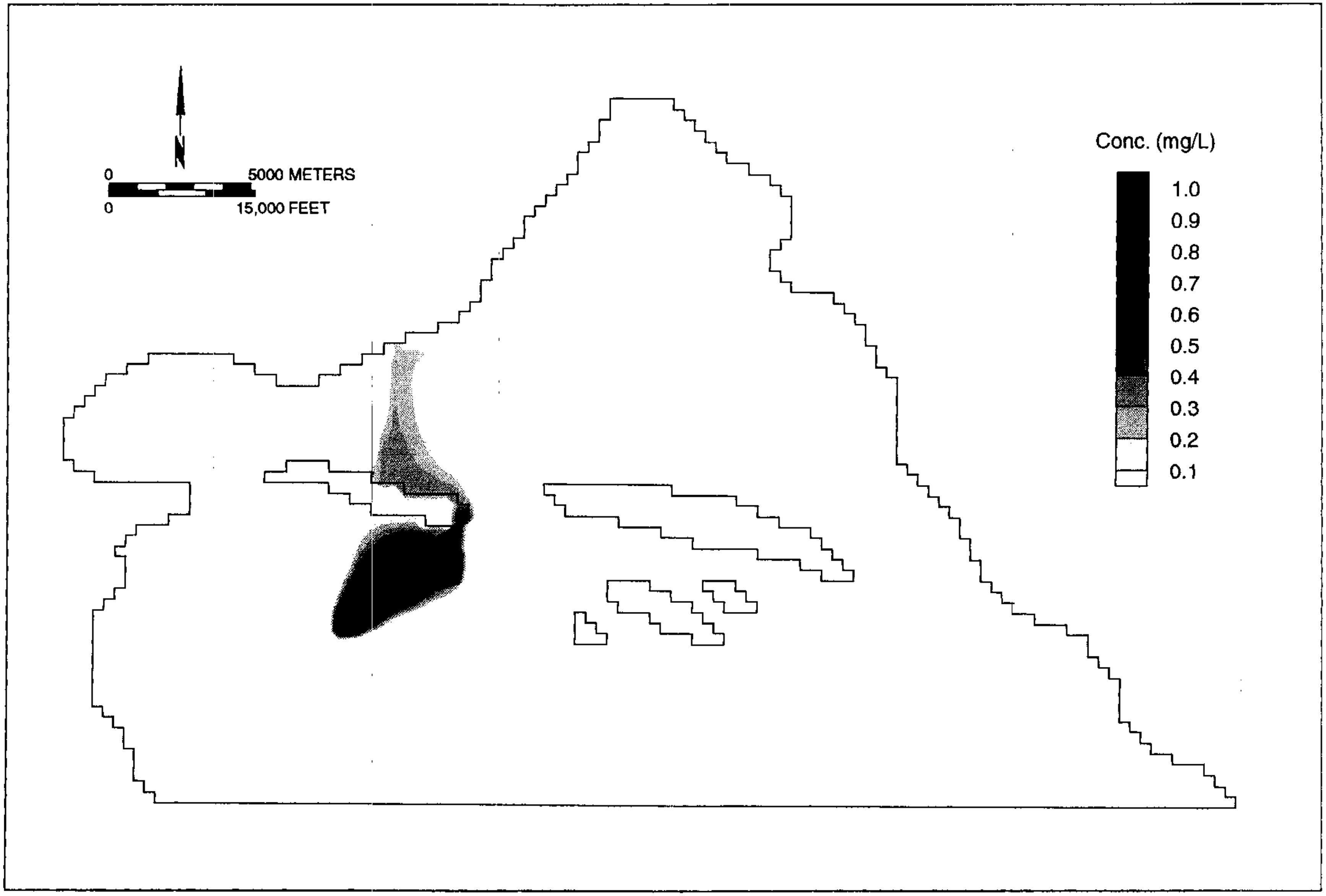

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Figure 12. Concentration Contours After 200 Years.

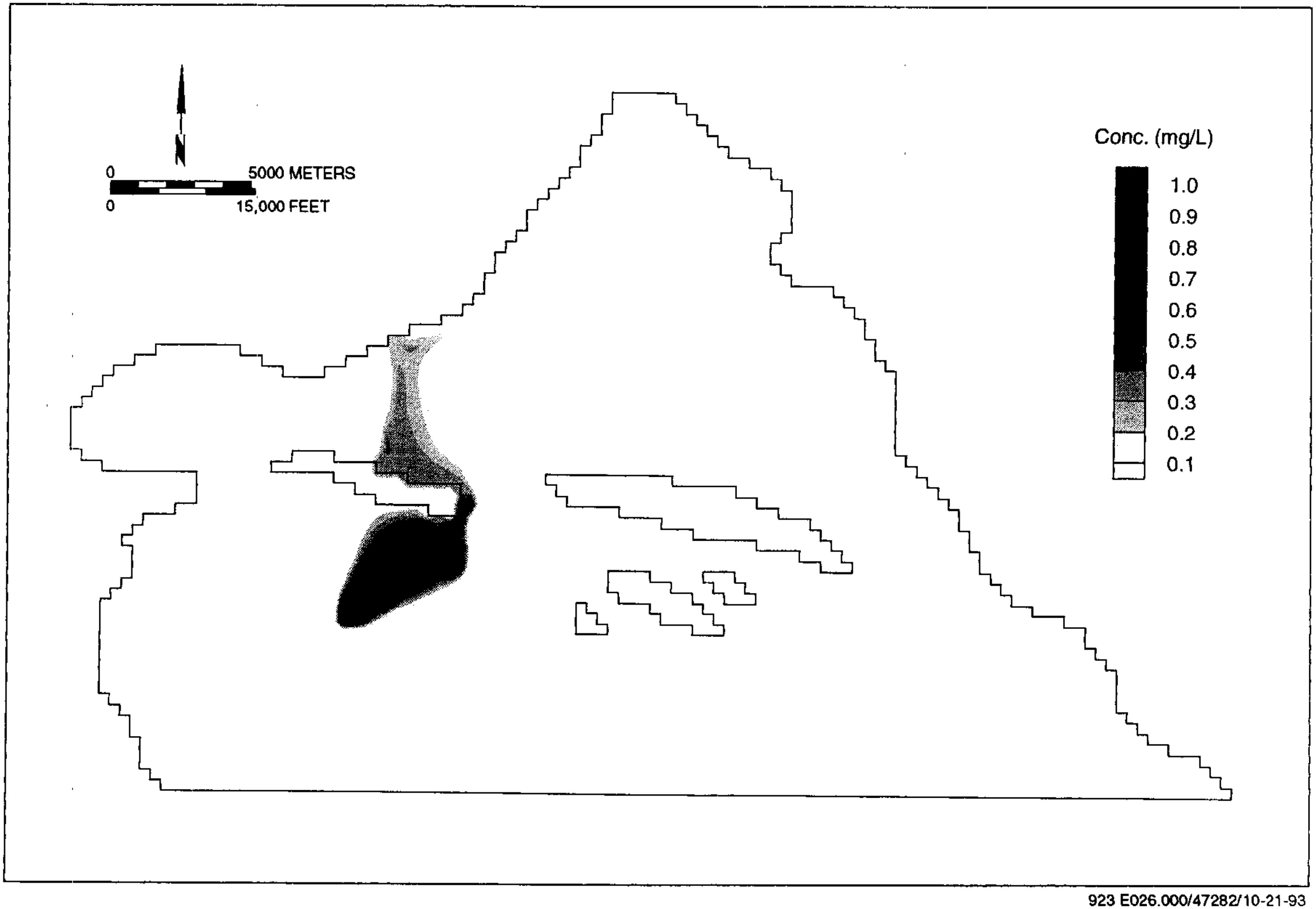

Figure 13. Concentration Contours After 300 Years.

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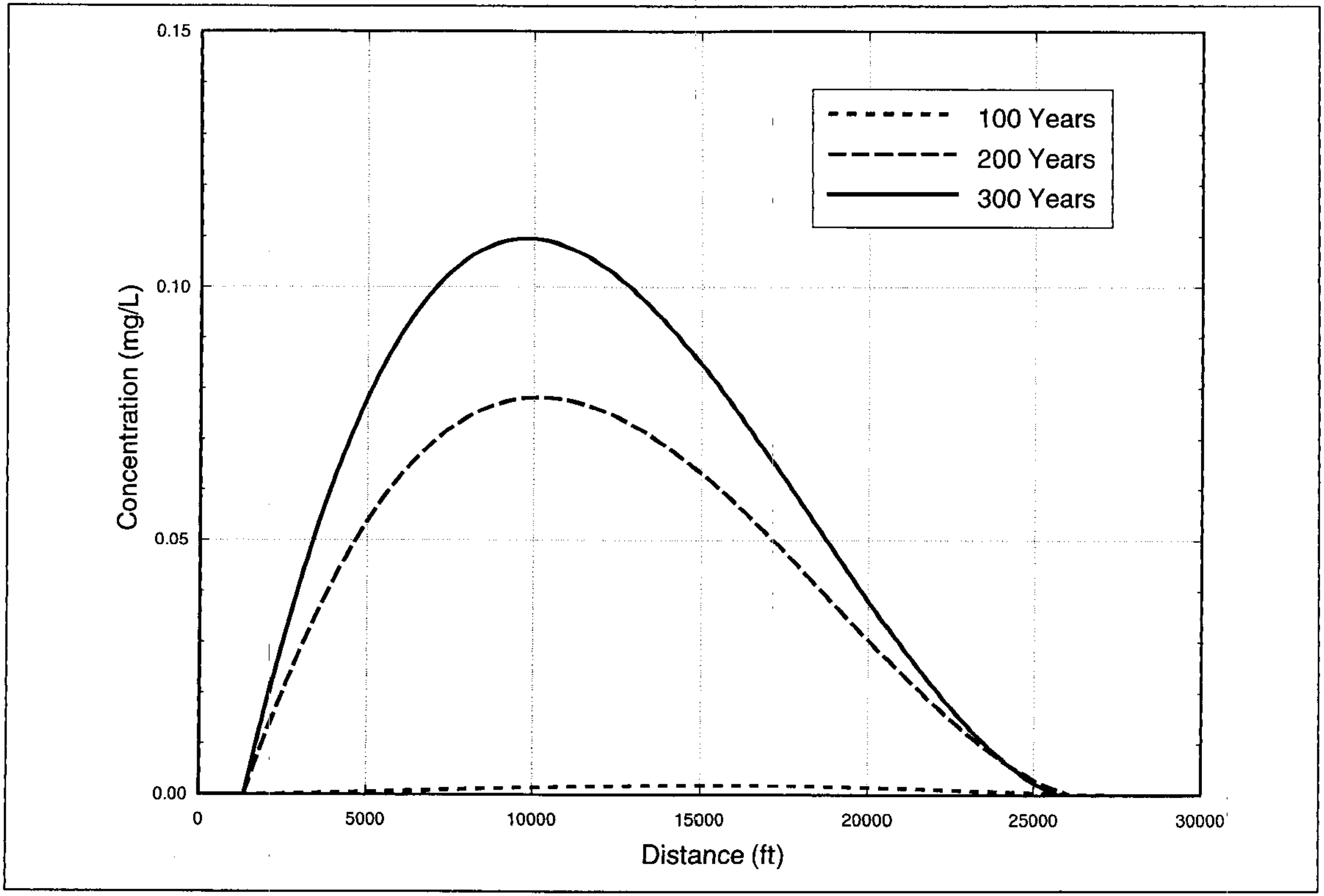

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Figure 14. Concentration Profiles at the Columbia River.

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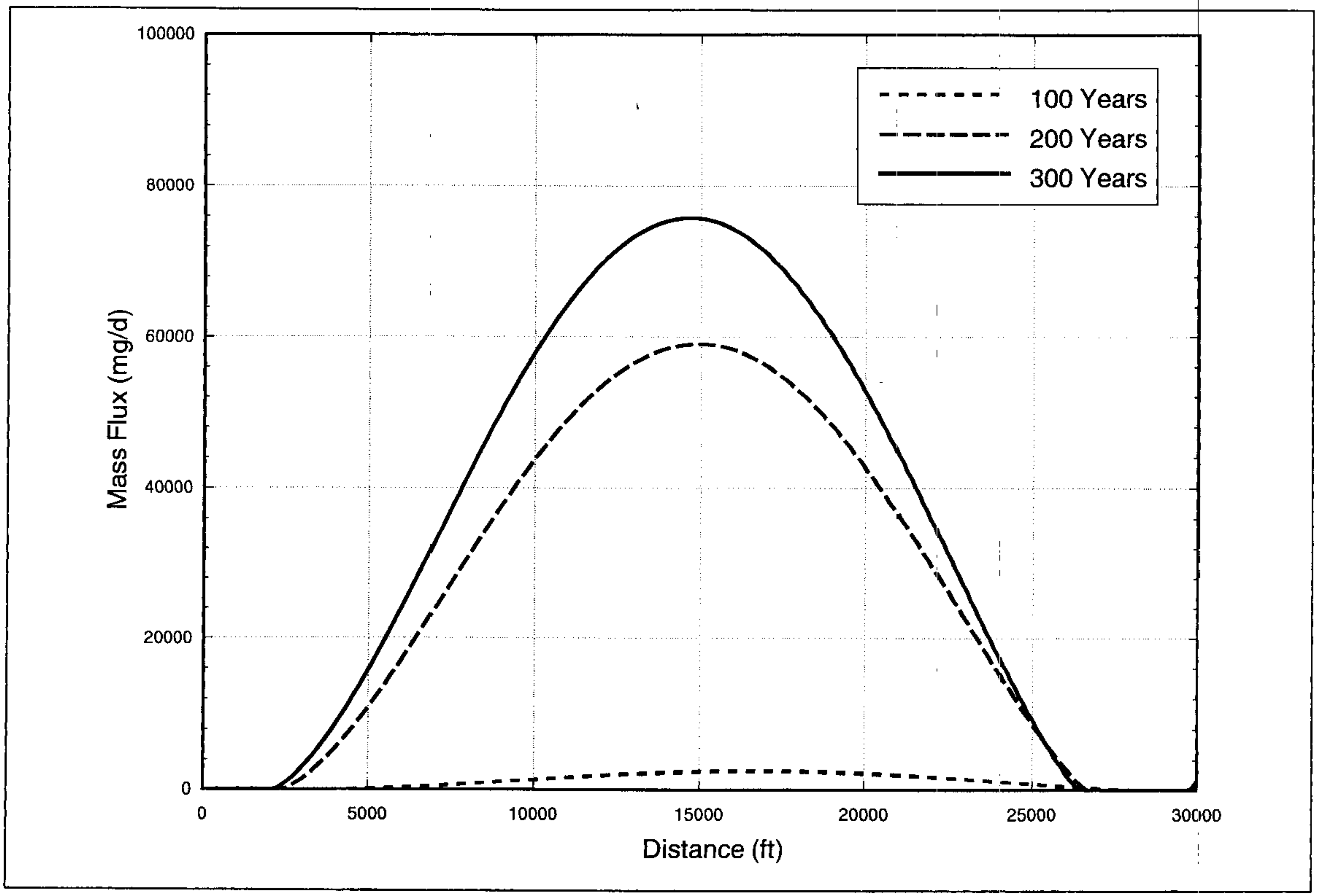

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Figure 15. Mass Flux Profiles at the Columbia River.

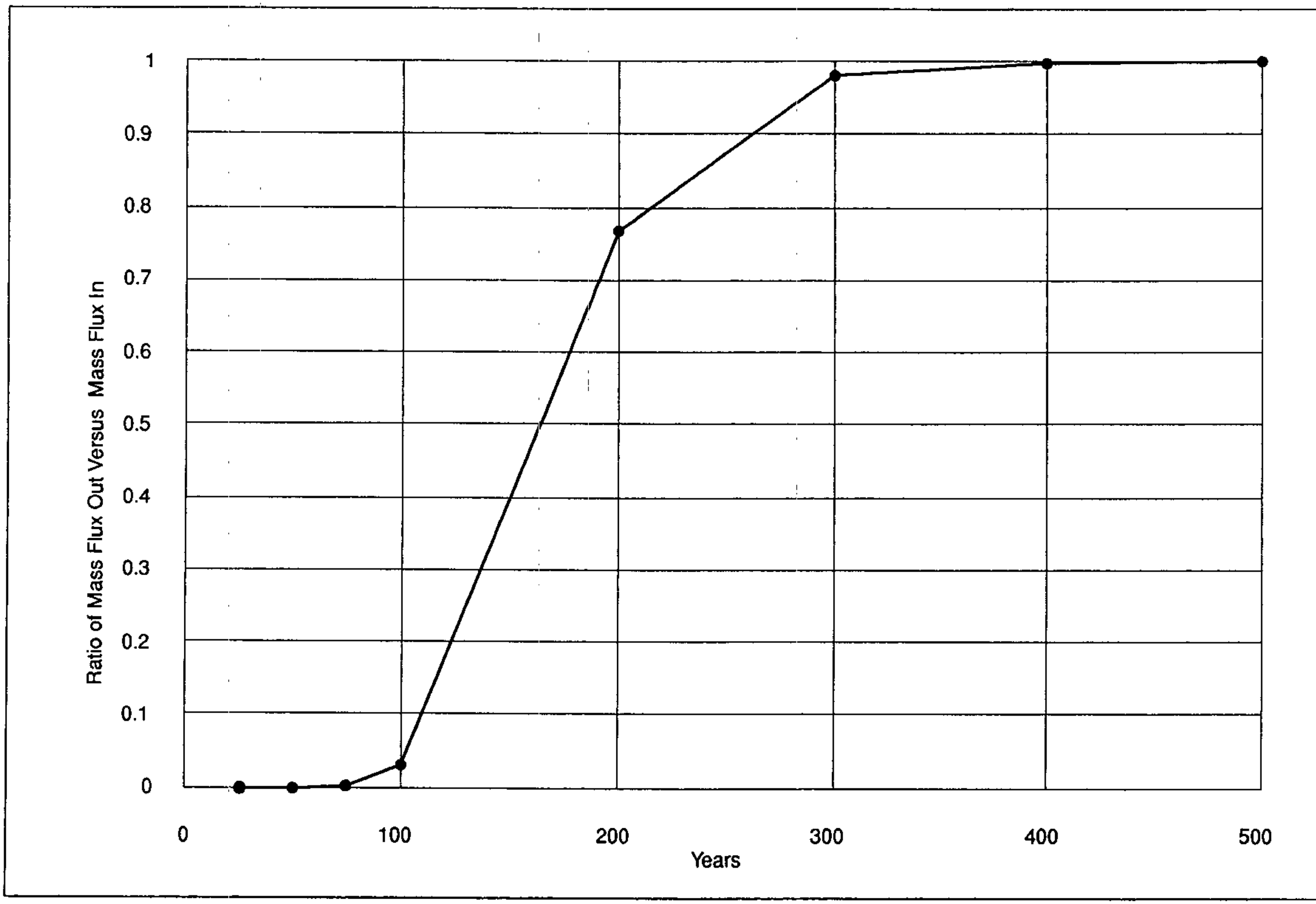

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Figure 16. Ratio of Mass Flux Leaving the Model Domain and Entering the Columbia River to Mass Flux Input to the Model.

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